

To: LeFranc, Maurice[LeFranc.Maurice@epa.gov]
Cc: Hockstad, Leif[Hockstad.Leif@epa.gov]; Alsalam, Jameel[Alsalam.Jameel@epa.gov]; Angel, Stacy[Angel.Stacy@epa.gov]; Fawcett, Allen[Fawcett.Allen@epa.gov]; Kocchi, Suzanne[Kocchi.Suzanne@epa.gov]; Krieger, Jackie[Krieger.Jackie@epa.gov]; Newberg, Cindy[Newberg.Cindy@epa.gov]; Birgfeld, Erin[Birgfeld.Erin@epa.gov]; DeLuca, Isabel[DeLuca.Isabel@epa.gov]; Irving, Bill[Irving.Bill@epa.gov]; Dunham, Sarah[Dunham.Sarah@epa.gov]; Craig, Beth[Craig.Beth@epa.gov]; Gunning, Paul[Gunning.Paul@epa.gov]; Harvey, Reid[Harvey.Reid@epa.gov]; Hufford, Drusilla[Hufford.Drusilla@epa.gov]; Mackay, Cheryl[Mackay.Cheryl@epa.gov]; Haman, Patricia[Haman.Patricia@epa.gov]; Lewis, Josh[Lewis.Josh@epa.gov]; Beauvais, Joel[Beauvais.Joel@epa.gov]; Drinkard, Andrea[Drinkard.Andrea@epa.gov]; McCabe, Janet[McCabe.Janet@epa.gov]; Ottinger, Deborah[Ottinger.Deborah@epa.gov]; Rand, Sally[Rand.Sally@epa.gov]; Sarofim, Marcus[Sarofim.Marcus@epa.gov]; DeAngelo, Ben[DeAngelo.Ben@epa.gov]
From: Hight, Cate
Sent: Mon 7/29/2013 7:43:05 PM
Subject: RE: LRM [EHF-113-128] Report on Climate Action Report - OAP comments
[NatCom6 Chapter 9 OAP.docx](#)
[Biennial Report OAP.docx](#)
[BR Methodologies Appendix OAP.docx](#)
[NatCom6 Chapter 3 OAP.docx](#)
[NatCom6 Chapter 4 OAP.docx](#)
[NatCom6 Chapter 4 Policies and Measures Annex OAP.xlsx](#)
[NatCom6 Chapter 5 OAP.docx](#)
[NatCom6 Chapter 7 OAP.docx](#)
[NatCom6 Chapter 8 OAP.docx](#)

Hi Maurice,

Attached are OAP's comments on 6th National Communication and the 1st Biennial Report. We've commented on the following items:

Ex. 5 - Deliberative Process

Please let me know if you have any questions.

Best,

Cate

Cate Hight

Climate Change Division

U.S. Environmental Protection Agency

202.343.9230

TELEWORK Tuesdays and Fridays: 240.426.5537

From: Irving, Bill

Sent: Monday, July 22, 2013 1:57 PM

To: Dunham, Sarah; Craig, Beth; Gunning, Paul; Harvey, Reid; Hufford, Drusilla

Cc: LeFranc, Maurice; Hockstad, Leif; Alsalam, Jameel; Angel, Stacy; Fawcett, Allen; Kocchi, Suzanne; Krieger, Jackie; Newberg, Cindy; Hight, Cate; Birgfeld, Erin; DeLuca, Isabel

Subject: FW: LRM [EHF-113-128] Report on Climate Action Report

Importance: High

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Ex. 5 - Deliberative Process

Ex. 5 - Deliberative Process

Thanks,

Bill

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Sent: Friday, July 19, 2013 3:22 PM

To: Krieger, Jackie; Orehowsky, Karen; Morales, Lourdes; Lubetsky, Jonathan; Ketcham-Colwill, Jim; Kocchi, Suzanne; Koo-Oshima, Sasha; Nishida, Jane; Scheraga, Joel; McGartland, Al; Piantanida, David

Cc: Mackay, Cheryl; Haman, Patricia; Lewis, Josh; Beauvais, Joel; Craig, Beth; Irving, Bill; Krieger, Jackie; Gunning, Paul; Drinkard, Andrea; McCabe, Janet; Dunham, Sarah

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We need your help to ensure that we have a thorough review of both reports. Please focus on those sections of CAR6 of the BR that are most relevant to your office's expertise. If you have additional comments on other sections those are welcomed as well.

The OMB guidance asks reviewers to "... **comment[s] on whether the U.S. climate change narrative comes across as clear and compelling.**" Although we would welcome your input on this aspect of the report, significant time has been spent, and will be spent, by senior management to ensure the messaging in this draft is accurate and appropriate (particularly on the BR).

The due date for completing the LRM process is August 1. In order to ensure we make this deadline please have you comments back to us no later than COB, July 29. Please copy all on the cc: line above in your response.

I will be on travel next week but will be able to respond to email questions. If you cannot reach me please contact Bill Irving or Andrea Drinkard (copied above).

Thank you for your help on this.

Maurice

From: Lewis, Josh
Sent: Friday, July 19, 2013 12:28 PM
To: Beauvais, Joel; LeFranc, Maurice
Cc: Mackay, Cheryl; Haman, Patricia; Lubetsky, Jonathan
Subject: FW: LRM [EHF-113-128] Report on Climate Action Report

Joel/Maurice,

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Give me a call if easier to discuss by phone.  Ex. 6 - Personal Privacy

Josh

DEADLINE: 5:00 PM Thursday, August 01, 2013 – FIRM DEADLINE

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We would also appreciate comments on whether the U.S. climate change narrative comes across as clear and compelling. Please return all comments to OMB by COB Thursday, August 1. This is a hard deadline.

-

Provide comments to: John MacNeil E-Mail: John S. MacNeil@ Ex. 6 - Personal Privacy PHONE: (202) 395-1096

LRM ID: EHF-113-128
EXECUTIVE OFFICE OF THE PRESIDENT
OFFICE OF MANAGEMENT AND BUDGET

LEGISLATIVE REFERRAL MEMORANDUM
Friday, July 19, 2013

TO: Legislative Liaison Officer - See Distribution

FROM: Burnim, John (for) Assistant Director for Legislative Reference
SUBJECT: LRM [EHF-113-128] Report on Climate Action Report

OMB CONTACT: **MacNeil, John**
E-Mail: John S. MacNeil@ Ex. 6 - Personal Privacy
PHONE: **(202) 395-1096**

In accordance with OMB Circular A-19, OMB requests the views of your agency on the above subject before advising on its relationship to the program of the President. By the deadline above, please reply by e-mail or telephone, using the OMB Contact information above.

Please advise us if this item will affect direct spending or receipts for the purposes of the Statutory Pay-as-You-Go Act of 2010.

Thank you.

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To: Irving, Bill[Irving.Bill@epa.gov]; Hight, Cate[Hight.Cate@epa.gov]
Cc: Angel, Stacy[Angel.Stacy@epa.gov]; Hockstad, Leif[Hockstad.Leif@epa.gov]; Alsalam, Jameel[Alsalam.Jameel@epa.gov]; Fawcett, Allen[Fawcett.Allen@epa.gov]; Godwin, Dave[Godwin.Dave@epa.gov]; Hufford, Drusilla[Hufford.Drusilla@epa.gov]; Horwitz, Paul[Horwitz.Paul@epa.gov]; Donaldson, David[Donaldson.David@epa.gov]
From: Newberg, Cindy
Sent: Fri 7/26/2013 7:44:50 PM
Subject: RE: LRM [EHF-113-128] Report on Climate Action Report
[Biennial Report-spd r1.docx](#)
[BR Methodologies Appendix-spd.docx](#)
[NatCom6 Chapter 3-spd.docx](#)
[NatCom6 Chapter 4 Policies and Measures Annex-spd.xlsx](#)
[NatCom6 Chapter 4-spd r1.docx](#)
[NatCom6 Chapter 5-spd.docx](#)

Bill/Cate-

Attached are SPD's comments. Please let Dave Godwin or I know if you have any questions/comments. Thanks,

-Cindy

From: Irving, Bill
Sent: Monday, July 22, 2013 1:57 PM
To: Dunham, Sarah; Craig, Beth; Gunning, Paul; Harvey, Reid; Hufford, Drusilla
Cc: LeFranc, Maurice; Hockstad, Leif; Alsalam, Jameel; Angel, Stacy; Fawcett, Allen; Kocchi, Suzanne; Krieger, Jackie; Newberg, Cindy; Hight, Cate; Birgfeld, Erin; DeLuca, Isabel
Subject: FW: LRM [EHF-113-128] Report on Climate Action Report
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CAR6 Chapter 3: Leif Hockstad

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CAR6 Chapter 5: Jameel Alsalam

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Cc: Mackay, Cheryl; Haman, Patricia; Lewis, Josh; Beauvais, Joel; Craig, Beth; Irving, Bill; Krieger, Jackie; Gunning, Paul; Drinkard, Andrea; McCabe, Janet; Dunham, Sarah

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Ex. 5 - Deliberative Process

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Ex. 6 - Personal Privacy

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Thank you for your help on this.

Maurice

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Cc: Mackay, Cheryl; Haman, Patricia; Lubetsky, Jonathan
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LRM ID: EHF-113-128
EXECUTIVE OFFICE OF THE PRESIDENT
OFFICE OF MANAGEMENT AND BUDGET

LEGISLATIVE REFERRAL MEMORANDUM
Friday, July 19, 2013

TO: Legislative Liaison Officer - See Distribution

FROM: Burnim, John (for) Assistant Director for Legislative Reference
SUBJECT: LRM [EHF-113-128] Report on Climate Action Report

OMB CONTACT: **MacNeil, John**

E-Mail: **Ex. 6 - Personal Privacy**

PHONE: **Ex. 6 - Personal Privacy**

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To: Newberg, Cindy[Newberg.Cindy@epa.gov]
Cc: Hufford, Drusilla[Hufford.Drusilla@epa.gov]; Horwitz, Paul[Horwitz.Paul@epa.gov]; Rim, Elisa[Rim.Elisa@epa.gov]; Hall-Jordan, Luke[Hall-Jordan.Luke@epa.gov]
From: Godwin, Dave
Sent: Fri 7/26/2013 1:42:41 AM
Subject: RE: LRM [EHF-113-128] Report on Climate Action Report
[BR Methodologies Appendix-spd.docx](#)
[Biennial Report-spd.docx](#)
[NatCom6 Chapter 3-spd.docx](#)
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[NatCom6 Chapter 4 Policies and Measures Annex-spd.xlsx](#)
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Ex. 5 - Deliberative Process

[BR Methodologies Appendix-spd.docx](#)

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[Biennial Report-spd.docx](#)

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[NatCom6 Chapter 3-spd.docx](#)

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[NatCom6 Chapter 4-spd.docx](#)

Ex. 5 - Deliberative Process

NatCom6 Chapter 4 Policies and Measures Annex-spd.xlsx

Ex. 5 - Deliberative Process

NatCom6 Chapter 5-spd.docx

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From: Newberg, Cindy
Sent: Monday, July 22, 2013 2:08 PM
To: Godwin, Dave
Cc: Hufford, Drusilla; Horwitz, Paul; Rim, Elisa; Hall-Jordan, Luke
Subject: FW: LRM [EHF-113-128] Report on Climate Action Report
Importance: High

Dave – let's take a look and see if there's HFC comments.

Cindy Newberg

Ex. 6 - Personal Privacy

From: Irving, Bill
Sent: Monday, July 22, 2013 1:57 PM
To: Dunham, Sarah; Craig, Beth; Gunning, Paul; Harvey, Reid; Hufford, Drusilla

Cc: LeFranc, Maurice; Hockstad, Leif; Alsalam, Jameel; Angel, Stacy; Fawcett, Allen; Kocchi, Suzanne; Krieger, Jackie; Newberg, Cindy; Hight, Cate; Birgfeld, Erin; DeLuca, Isabel

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LRM ID: EHF-113-128
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OMB CONTACT: **MacNeil, John**

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To: Horwitz, Paul[Horwitz.Paul@epa.gov]; Godwin, Dave[Godwin.Dave@epa.gov]; Rim, Elisa[Rim.Elisa@epa.gov]
Cc: Hufford, Drusilla[Hufford.Drusilla@epa.gov]
From: Newberg, Cindy
Sent: Tue 7/16/2013 7:36:46 PM
Subject: FW: BR draft revisions and annex
[BR Report July 16 EPA OAR.docx](#)

FYI – here's what Maurice sent to CEQ on the BR. The annex is still pending.

Cindy Newberg

Ex. 6 - Personal Privacy

From: LeFranc, Maurice
Sent: Tuesday, July 16, 2013 3:21 PM
To: Larsen, Kate
Cc: Dunham, Sarah; Beauvais, Joel; Gunning, Paul; Kocchi, Suzanne; Fawcett, Allen; Hufford, Drusilla; Newberg, Cindy; Craig, Beth; Hockstad, Leif; Alsalam, Jameel; Angel, Stacy; Irving, Bill; Krieger, Jackie; Goffman, Joseph; Duke, Rick
Subject: RE: BR draft revisions and annex

Kate:

Attached is the BR draft with additional comments. Hope these are helpful. I will get back to you on the methodologies piece shortly. Have a couple of remaining issues to address.

Maurice

From: Larsen, Kate [mailto:Kate_M_Larsen@ceq.eop.gov]
Sent: Sunday, July 14, 2013 3:46 PM
To: LeFranc, Maurice
Cc: Dunham, Sarah; Beauvais, Joel; Gunning, Paul; Kocchi, Suzanne; Fawcett, Allen; Hufford, Drusilla; Newberg, Cindy; Craig, Beth; Hockstad, Leif; Alsalam, Jameel; Angel, Stacy; Irving, Bill; Krieger, Jackie; Goffman, Joseph; Duke, Rick
Subject: BR draft revisions and annex

Thanks again for all your work on this. Attached is our revised draft BR which incorporates all of your comments. Revised language is in tracked changes, but in general all your comments were accepted or addressed. There are several places where additional changes are requested, based on your comments.

Ex. 5 - Deliberative Process

Please review the draft appendix and let us know what edits you would like to make by COB Tuesday, July 16. Once we wrap up these last few elements, we will finalize the draft for interagency review.

Thanks everyone,
Kate

Kate M. Larsen
Deputy Associate Director
Energy and Climate Change
White House Council on Environmental Quality

-----Original Message-----

From: LeFranc, Maurice [LeFranc.Maurice@epa.gov]

Sent: Friday, July 12, 2013 04:12 PM Eastern Standard Time

To: Larsen, Kate

Cc: Dunham, Sarah; Beauvais, Joel; Gunning, Paul; Kocchi, Suzanne; Fawcett, Allen;

Hufford, Drusilla; Newberg, Cindy; Craig, Beth; Hockstad, Leif; Alsalam, Jameel; Angel, Stacy; Irving, Bill; Krieger, Jackie; Goffman, Joseph
Subject: RE: EPA/OAR comments on early BR draft

Kate:

Here are our initial comments on the BR. A few points:

Ex. 5 - Deliberative Process

Otherwise, thanks for all of you work in pulling this together.

Maurice

From: Irving, Bill
Sent: Friday, July 12, 2013 3:56 PM
To: LeFranc, Maurice
Cc: Dunham, Sarah; Beauvais, Joel; Gunning, Paul; Kocchi, Suzanne; Fawcett, Allen; Hufford, Drusilla; Newberg, Cindy; Craig, Beth; Hockstad, Leif; Alsalam, Jameel; Angel, Stacy; Haeuber, Richard
Subject: RE: OAP comments on early BR draft

Maurice

No additional comments.

Bill

From: LeFranc, Maurice
Sent: Friday, July 12, 2013 3:20 PM
To: Irving, Bill
Cc: Dunham, Sarah; Beauvais, Joel; Gunning, Paul; Kocchi, Suzanne; Fawcett, Allen; Hufford, Drusilla; Newberg, Cindy; Craig, Beth; Hockstad, Leif; Alsalam, Jameel; Angel, Stacy; Haeuber, Richard
Subject: RE: OAP comments on early BR draft

Attached is the most recent draft of our consolidated comments on the BR including my comments, those from OAP and Joel's. Please look over and let me know if you have any additional comments or any concerns with comments on the edits.

I plan to send these over to CEQ at 4:00 so please get back to me before then. If I don't hear back I will assume you have no further comments.

Thank you for all of your help with these.

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Subject: OAP comments on early BR draft

Maurice

Attached are consolidated OAP comments on CEQ's draft BR from 7/9.

Ex. 5 - Deliberative Process

Ex. 5 - Deliberative Process

Bill

Chief, Climate Policy Branch

Climate Change Division, Office of Atmospheric Programs

USEPA

+1 (202) 343 9065 tel

+1 (202) 343 2357 fax

Ex. 6 - Personal Privacy mobile

To: Godwin, Dave[Godwin.Dave@epa.gov]; Horwitz, Paul[Horwitz.Paul@epa.gov]; Hufford, Drusilla[Hufford.Drusilla@epa.gov]; Rim, Elisa[Rim.Elisa@epa.gov]; Hall-Jordan, Luke[Hall-Jordan.Luke@epa.gov]
From: Newberg, Cindy
Sent: Tue 7/30/2013 8:22:17 PM
Subject: FW: LRM [EHF-113-128] Report on Climate Action Report
[NatCom6 Chapter 4 EPA.docx](#)
[BR Methodologies Appendix EPA.docx](#)
[Biennial Report EPA.docx](#)
[NatCom6 Chapter 1 EPA.docx](#)
[NatCom6 Chapter 6 \(2\).docx](#)
[NatCom6 Chapter 8 EPA.docx](#)
[NatCom6 Chapter 5 EPA.docx](#)
[NatCom6 Chapter 3 EPA.docx](#)
[NatCom6 Chapter 4 Policies and Measures Annex EPA.xlsx](#)
[NatCom6 Chapter 9 EPA.docx](#)
[NatCom6 Chapter 2 EPA.docx](#)
[CAR Foreword EPA.docx](#)
[NatCom6 Chapter 7 EPA.docx](#)

Cindy Newberg

Ex. 6 - Personal Privacy

From: Irving, Bill
Sent: Tuesday, July 30, 2013 3:58 PM
To: Hockstad, Leif; Alsalam, Jameel; Ohrel, Sara; Newberg, Cindy; Angel, Stacy
Subject: FW: LRM [EHF-113-128] Report on Climate Action Report

FYI – for your records.

From: LeFranc, Maurice
Sent: Tuesday, July 30, 2013 3:53 PM
To: Lewis, Josh
Cc: Mackay, Cheryl; Haman, Patricia; Beauvais, Joel; Craig, Beth; Irving, Bill; Krieger, Jackie; Gunning, Paul; Drinkard, Andrea; McCabe, Janet; Dunham, Sarah; Evarts, Dale; Morales, Lourdes; Hight, Cate; Franklin, Pamela; Socci, Anthony

Subject: RE: LRM [EHF-113-128] Report on Climate Action Report

Josh:

Here are the reviewed chapters from CAR6 and the Biennial report. I got good coverage from OAR (OAP and OAQPS) and some feedback from OITA. Otherwise I did not hear from any of the other offices. I asked for feedback by COB yesterday so am sending you what I have in order to be timely in our response to OMB.

Let me know if you have any questions. Not sure if it would be worth you reaching out to the other offices for additional comments. If so, we would then have to review them to ensure none of the comments counter carefully worded chapters in some cases.

Maurice

From: LeFranc, Maurice

Sent: Friday, July 19, 2013 3:22 PM

To: Krieger, Jackie; Orehowsky, Karen; Morales, Lourdes; Lubetsky, Jonathan; Ketcham-Colwill, Jim; Kocchi, Suzanne; Koo-Oshima, Sasha; Nishida, Jane; Scheraga, Joel; McGartland, Al; Piantanida, David

Cc: Mackay, Cheryl; Haman, Patricia; Lewis, Josh; Beauvais, Joel; Craig, Beth; Irving, Bill; Krieger, Jackie; Gunning, Paul; Drinkard, Andrea; McCabe, Janet; Dunham, Sarah

Subject: FW: LRM [EHF-113-128] Report on Climate Action Report

To all:

Please see email below from Josh Lewis transmitting the draft of the Sixth Climate Action Report and the Biennial Report (BR) through an OMB LRM process. The Office of Air and Radiation has been involved in the drafting of CAR6 (and lead on three chapters) as well as the development of the draft Biennial Report. We have offered to coordinate with Josh and his colleagues to help manage the LRM process and to work through the set of comments that we receive.

We need your help to ensure that we have a thorough review of both reports. Please focus on those sections of CAR6 of the BR that are most relevant to your office's expertise. If you have additional comments on other sections those are welcomed as well.

The OMB guidance asks reviewers to "... comment[s] on whether the U.S. climate change narrative comes across as clear and compelling."

Ex. 5 - Deliberative Process

Ex. 5 - Deliberative Process

The due date for completing the LRM process is August 1. In order to ensure we make this deadline please have your comments back to us no later than COB, July 29. Please copy all on the cc: line above in your response.

Ex. 6 - Personal Privacy

If you cannot reach me please contact Bill Irving or Andrea Drinkard (copied above).

Thank you for your help on this.

Maurice

From: Lewis, Josh
Sent: Friday, July 19, 2013 12:28 PM
To: Beauvais, Joel; LeFranc, Maurice
Cc: Mackay, Cheryl; Haman, Patricia; Lubetsky, Jonathan
Subject: FW: LRM [EHF-113-128] Report on Climate Action Report

Joel/Maurice,

See attached and below...OMB is circulating for clearance the climate action report. I'm assuming one or both of you have been involved in drafts of this? Any thoughts on how best to proceed with Agency review, and whether OAR or OITA (or some other office) should be the lead? I don't think it makes a ton of sense for OCIR to be the lead at this point.

Give me a call if easier to discuss by phone. 202 329 2291

Josh

DEADLINE: 5:00 PM Thursday, August 01, 2013 – FIRM DEADLINE

This 2014 Climate Action Report consists of two documents that respond to reporting requirements under the UN Framework Convention on Climate Change. These documents, the sixth National Communication and the first Biennial Report, set out major actions the U.S. government is taking at the federal level, highlight examples of state and local actions, and outline U.S. efforts to assist other countries in addressing climate change. Each document meets specific UN reporting requirements, resulting in significant overlap between the documents.

One key difference is that the Biennial Report, which is meant to demonstrate progress toward the U.S. 2020 emissions reduction target, covers the President's 2013 Climate Action Plan in greater depth and provides estimates of expected emissions reductions in 2020. Please review both documents for accuracy, consistency, and completeness.

We would also appreciate comments on whether the U.S. climate change narrative comes across as clear and compelling. Please return all comments to OMB by COB Thursday, August 1. This is a hard deadline.

-

Provide comments to: John MacNeil E-Mail: Ex. 6 - Personal Privacy PHONE:
Ex. 6 - Personal Privacy

LRM ID: EHF-113-128
EXECUTIVE OFFICE OF THE PRESIDENT
OFFICE OF MANAGEMENT AND BUDGET

LEGISLATIVE REFERRAL MEMORANDUM
Friday, July 19, 2013

TO: Legislative Liaison Officer - See Distribution

FROM: Burnim, John (for) Assistant Director for Legislative Reference
SUBJECT: LRM [EHF-113-128] Report on Climate Action Report

OMB CONTACT: **MacNeil, John**

E-Mail: **Ex. 6 - Personal Privacy**

PHONE: **Ex. 6 - Personal Privacy**

In accordance with OMB Circular A-19, OMB requests the views of your agency on the above subject before advising on its relationship to the program of the President. By the deadline above, please reply by e-mail or telephone, using the OMB Contact information above.

Please advise us if this item will affect direct spending or receipts for the purposes of the Statutory Pay-as-You-Go Act of 2010.

Thank you.

(See attached file: Biennial Report.docx)(See attached file: BR Methodologies Appendix.docx)(See attached file: CAR_Foreword.docx)(See attached file: NatCom6 Chapter 1.docx)(See attached file: NatCom6 Chapter 2.docx)(See attached file: NatCom6 Chapter 3.docx)(See attached file: NatCom6 Chapter 4 Policies and Measures Annex.xlsx)(See attached file: NatCom6 Chapter 4.docx)(See attached file: NatCom6 Chapter 5.docx)(See attached file: NatCom6 Chapter 6.docx)(See attached file: NatCom6 Chapter 7 Tables.docx)(See attached file: NatCom6 Chapter 7.docx)(See

attached file: NatCom6 Chapter 8.docx)(See attached file: NatCom6 Chapter 9 Table 9.1.xlsx)(See attached file: NatCom6 Chapter 9.docx)

To: Irving, Bill[Irving.Bill@epa.gov]
From: Gordon, Jessica M
Sent: Fri 3/8/2013 9:36:03 PM
Subject: RE: Petition for Rulemakings to Control GHGs, under Section 115, Title VI, Section 111, and Title II of the Clean Air Act
[CAA 115 petition notes 3-8-13.docx](#)

Bill, here's the current draft; let me know if you have any edits or want me to send this one to Suzie et al. Thanks.
Jessica

From: Irving, Bill
Sent: Friday, March 08, 2013 4:19 PM
To: Gordon, Jessica M
Subject: RE: Petition for Rulemakings to Control GHGs, under Section 115, Title VI, Section 111, and Title II of the Clean Air Act

I'd like to take a look at what you have before you pass it along – afterwards, it should go directly to Paul, copying me, Suzie, Allen and Rona. It will come up at Monday morning's OAP management meeting.

For my input, I have only one policy point, below. Also, I spoke with a friend who works on these issues and got some interesting feedback. I can fill you in by phone if you're interested.

Ex. 5 - Deliberative Process

From: Gordon, Jessica M
Sent: Friday, March 08, 2013 4:11 PM
To: Irving, Bill
Subject: RE: Petition for Rulemakings to Control GHGs, under Section 115, Title VI, Section 111, and Title II of the Clean Air Act

I didn't get any comments from Cate; did you have anything or should I just send this to Suzie? Thanks.

Jessica

From: Irving, Bill
Sent: Friday, March 08, 2013 3:45 PM
To: Gordon, Jessica M
Subject: FW: Petition for Rulemakings to Control GHGs, under Section 115, Title VI, Section 111, and Title II of the Clean Air Act

Jessica – checking in on how this is going.

Bill

From: Irving, Bill
Sent: Thursday, March 07, 2013 5:43 PM
To: Gordon, Jessica M
Subject: RE: Petition for Rulemakings to Control GHGs, under Section 115, Title VI, Section 111, and Title II of the Clean Air Act

I think we're good to go. I've been crashing on biomass, but will try to read it myself tomorrow morning.

From: Gordon, Jessica M
Sent: Thursday, March 07, 2013 5:42 PM
To: Irving, Bill
Subject: RE: Petition for Rulemakings to Control GHGs, under Section 115, Title VI, Section 111, and Title II of the Clean Air Act

Bill, Cate is going to send comments shortly, but here are the other compiled comments. Let me know if you'd like anything else (besides adding whatever Cate sends); thanks.

Jessica

Jessica M. Gordon
Legal Advisor, Climate Change Division
U.S. Environmental Protection Agency
(202) 343-9444
gordon.jessica@epa.gov

This message may contain privileged or other confidential information.
Please do not forward or distribute it outside of EPA.

From: Irving, Bill
Sent: Thursday, March 07, 2013 12:01 PM
To: Gordon, Jessica M; Hight, Cate; Sherry, Christopher; Hockstad, Leif
Subject: FW: Petition for Rulemakings to Control GHGs, under Section 115, Title VI, Section 111, and Title II of the Clean Air Act
Importance: High

All, please take a look and send general comments/observations to Jessica by 4pm so that she can consolidate for CPB.

It's not entirely clear what the focus should be, but take a look and see what you find.

From: Kocchi, Suzanne
Sent: Thursday, March 07, 2013 11:12 AM
To: Irving, Bill; Fawcett, Allen
Cc: Gunning, Paul
Subject: FW: Petition for Rulemakings to Control GHGs, under Section 115, Title VI, Section 111, and Title II of the Clean Air Act

Can you please talk a look and give me any bullets you have by cob today, preferably?

From: Krieger, Jackie
Sent: Thursday, March 07, 2013 11:09 AM
To: Gunning, Paul; Hufford, Drusilla; Harvey, Reid; Craig, Beth
Cc: Dunham, Sarah; Kocchi, Suzanne; Kertcher, Larry; Angel, Stacy; Birnbaum, Rona; Newberg, Cindy; Donaldson, David
Subject: FW: Petition for Rulemakings to Control GHGs, under Section 115, Title VI, Section 111, and Title II of the Clean Air Act

As discussed this morning, here is the file with the NYU petition for EPA to regulate GHGs under CAA 115, 615, and 111/Title II. OGC has asked for initial reactions from both OAP and OAQPS. You (particularly CCD and SPD) should review, and then let's have a brief follow-up discussion during next Monday's OAP management meeting (3/11) where we can confirm how to consolidate our comments, get back to OGC, and other next steps.

From: jaschwartz@gmail.com [<mailto:jaschwartz@gmail.com>] **On Behalf Of** Jason Schwartz
Sent: Tuesday, February 19, 2013 10:23 AM
To: Bob Perciasepe; Mccarthy, Regina; Imohiosen, Charles; Goo, Michael; Dale, Sarah; Cristofaro, Alexander; Mallory, Brenda; Auerbacher, Kevin; schmidt.lori@epa.gov; Siciliano, CarolAnn; Beauvais, Joel; Dunham, Sarah; Hufford, Drusilla; Grundler, Christopher; Simon, Karl; DePass, Michelle; Smith, Walker
Cc: Michael A Livermore
Subject: Petition for Rulemakings to Control GHGs, under Section 115, Title VI, Section 111, and Title II of the Clean Air Act

Dear Acting Administrator Perciasepe -

The Institute for Policy Integrity submits the attached petition for regulating greenhouse gases under the Clean Air Act. The petition principally asserts that all the criteria to trigger mandatory action under Section 115 have been satisfied for greenhouse gases, and further explains how Section 115 provides for an efficient and comprehensive response to climate change. In the alternative, the petition asks EPA to issue a public call for information to explore whether the science supports triggering mandatory regulation under Title VI of the statute, which could also offer an efficient and comprehensive approach to greenhouse gases. As a third-best option, EPA could continue developing sector-by-sector regulations under the two statutory authorities it has already invoked for greenhouse gases--Section 111 and Title II--and so Policy Integrity further petitions EPA to use those provisions to control emissions from every significant source not yet regulated.

Policy Integrity looks forward to EPA's response to this petition, and is eager to work with the agency on crafting the kind of efficient, economy-wide approach to greenhouse gases necessary to address the dangers of climate change. Please contact us to discuss any of these issues further.

Sincerely,

Jason A Schwartz, Legal Director
Institute for Policy Integrity
New York University School of Law
Wilf Hall, Room 317
139 MacDougal Street, New York, NY 10012
(212) 998-6093
www.policyintegrity.org

 [Follow Policy Integrity on Twitter](#)

To: Irving, Bill[Irving.Bill@epa.gov]; Kocchi, Suzanne[Kocchi.Suzanne@epa.gov]; Gunning, Paul[Gunning.Paul@epa.gov]
From: Birnbaum, Rona
Sent: Thur 3/7/2013 10:45:36 PM
Subject: FW: Petition for Rulemakings to Control GHGs, under Section 115, Title VI, Section 111, and Title II of the Clean Air Act
[2009 Endangerment TSD excepts on climate change strat ozone.docx](#)

FYI, here is what we sent to Jessica.

From: Jantarasami, Lesley
Sent: Thursday, March 07, 2013 4:06 PM
To: Gordon, Jessica M
Cc: Birnbaum, Rona; DeAngelo, Ben
Subject: RE: Petition for Rulemakings to Control GHGs, under Section 115, Title VI, Section 111, and Title II of the Clean Air Act

Hi Jessica,

Since we've heard you are coordinating comments on this petition, here is some input from CSIB. Please let us know if you have any questions.

Ex. 5 - Deliberative Process

Ex. 5 - Deliberative Process

Cheers,

Lesley

From: Birnbaum, Rona
Sent: Thursday, March 07, 2013 12:56 PM
To: DeAngelo, Ben; Jantarasami, Lesley
Subject: FW: Petition for Rulemakings to Control GHGs, under Section 115, Title VI, Section 111, and Title II of the Clean Air Act

From: Irving, Bill
Sent: Thursday, March 07, 2013 12:21 PM
To: Birnbaum, Rona
Subject: FW: Petition for Rulemakings to Control GHGs, under Section 115, Title VI, Section 111, and Title II of the Clean Air Act

Here's the second one – shorter fuse. Jessica is coordinating CPB comments so you could optionally send any CSIB input to her by 4pm. Shaun and Jared are looking at it for CEB.

From: Kocchi, Suzanne
Sent: Thursday, March 07, 2013 11:12 AM
To: Irving, Bill; Fawcett, Allen
Cc: Gunning, Paul
Subject: FW: Petition for Rulemakings to Control GHGs, under Section 115, Title VI, Section 111, and Title II of the Clean Air Act

Can you please talk a look and give me any bullets you have by cob today, preferably?

From: Krieger, Jackie

Sent: Thursday, March 07, 2013 11:09 AM

To: Gunning, Paul; Hufford, Drusilla; Harvey, Reid; Craig, Beth

Cc: Dunham, Sarah; Kocchi, Suzanne; Kertcher, Larry; Angel, Stacy; Birnbaum, Rona; Newberg, Cindy; Donaldson, David

Subject: FW: Petition for Rulemakings to Control GHGs, under Section 115, Title VI, Section 111, and Title II of the Clean Air Act

As discussed this morning, here is the file with the NYU petition for EPA to regulate GHGs under CAA 115, 615, and 111/Title II. OGC has asked for initial reactions from both OAP and OAQPS. You (particularly CCD and SPD) should review, and then let's have a brief follow-up discussion during next Monday's OAP management meeting (3/11) where we can confirm how to consolidate our comments, get back to OGC, and other next steps.

From: jaschwartz@gmail.com [<mailto:jaschwartz@gmail.com>] **On Behalf Of** Jason Schwartz

Sent: Tuesday, February 19, 2013 10:23 AM

To: Bob Perciasepe; Mccarthy, Regina; Imohiosen, Charles; Goo, Michael; Dale, Sarah; Cristofaro, Alexander; Mallory, Brenda; Auerbacher, Kevin; schmidt.lori@epa.gov; Siciliano, CarolAnn; Beauvais, Joel; Dunham, Sarah; Hufford, Drusilla; Grundler, Christopher; Simon, Karl; DePass, Michelle; Smith, Walker

Cc: Michael A Livermore

Subject: Petition for Rulemakings to Control GHGs, under Section 115, Title VI, Section 111, and Title II of the Clean Air Act

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Policy Integrity looks forward to EPA's response to this petition, and is eager to work with the

agency on crafting the kind of efficient, economy-wide approach to greenhouse gases necessary to address the dangers of climate change. Please contact us to discuss any of these issues further.

Sincerely,

Jason A Schwartz, Legal Director
Institute for Policy Integrity
New York University School of Law
Wilf Hall, Room 317
139 MacDougal Street, New York, NY 10012
(212) 998-6093
www.policyintegrity.org



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To: Kocchi, Suzanne[Kocchi.Suzanne@epa.gov]; Karimjee, Anhar[Karimjee.Anhar@epa.gov]; Irving, Bill[Irving.Bill@epa.gov]; Birnbaum, Rona[Birnbaum.Rona@epa.gov]; Fawcett, Allen[Fawcett.Allen@epa.gov]; Birgfeld, Erin[Birgfeld.Erin@epa.gov]
Cc: Gunning, Paul[Gunning.Paul@epa.gov]; DeBolt, Gloria[DeBolt.Gloria@epa.gov]; Waltzer, Suzanne[Waltzer.Suzanne@epa.gov]
From: Franklin, Pamela
Sent: Wed 4/17/2013 8:16:49 PM
Subject: RE: Strategic Plan Updates -- Due COB 4/23
FY 11-14 Plan_ncpb.docx

Suzie,

Attached is the strategic plan update with just one text edit (adding in explicitly CCAC on page 2).

I am loathe to ask this question,

Ex. 5 - Deliberative Process

Ex. 5 - Deliberative Process

Thanks,

Pamela

From: Kocchi, Suzanne
Sent: Thursday, April 11, 2013 1:57 PM
To: Karimjee, Anhar; Franklin, Pamela; Irving, Bill; Birnbaum, Rona; Fawcett, Allen; Birgfeld, Erin
Cc: Gunning, Paul; DeBolt, Gloria
Subject: FW: Strategic Plan Updates -- Due COB 4/23

See Ed's note below. We have to update the text in these docs as appropriate – in particular GHGRP and GMI are called out on page 2 of the strategic plan. And Anhar the Strategic Measures spreadsheet has the GHGRP goal.

Please send me your edits, **NLT 4/18** (but earlier, if possible) so I can get in one document, have Paul review and then we can send to Ed by his deadline.

Thanks!

From: Callahan, Ed
Sent: Thursday, April 11, 2013 1:44 PM
To: Craig, Beth; Hufford, Drusilla; Harvey, Reid; Gunning, Paul
Cc: Dunham, Sarah; Krieger, Jackie; Angel, Stacy; Bailey, MarySusan; Kertcher, Larry; Price, Doris; Kocchi, Suzanne
Subject: Strategic Plan Updates -- Due COB 4/23

Due COB, April 23

As I mentioned in our Management Meeting on March 18, EPA has started the process of creating its FY 2014-2018 Strategic Plan – a process that will culminate in EPA submitting its Strategic Plan to Congress along with our FY 2015 President’s Budget in February of 2014.

Attached is the latest request in EPA’s Strategic Planning process – a request to update and refine our narrative from EPA’s FY 2011-2014 Strategic Plan and to update/add/delete any of our existing Strategic Measures.

Please read the attached email request, follow the directions, and submit your updates to me by COB, April 23. I will consolidate your updates into a single document for Sarah’s review.

Thanks

Ed

From: Walters, Margaret

Sent: Wednesday, April 10, 2013 3:30 PM

To: Haley, Mike; McCubbin, Courtney; Callahan, Ed; Duncan, Anna; Logan, Kia; Whitlow, Jeff; Holt, Kay; Jones, Mike; Mitchell, Ken

Cc: Kemker, Carol; Gettle, Jeaneanne; Salgado, Omayra; Higgins, Becky; LaRue, Steven

Subject: Response Request by COB 4/24: Next Steps on Strategic Plan

The emphasis for the FY 2014-2018 Strategic Plan update is *fine-tuning*. Your edits and comments are due to me by COB Wednesday, 4/24.

We're being asked to provide updates and/or new information for the following:

1. *Goal Overview and Narrative*

- The narrative from the FY 11-14 Plan is attached with requests for updates. Please use redline/strikeout.

2. *Strategic Measures Updates*

- Our Strategic Measures are attached with OCFO comments for consideration only. Use third column for redline/strikeout edits/updates.

3. *Program Evaluation Template Submissions*

- Use Template 1 for Past Evaluations and Template 2 for Planned Evaluations. Include IG and GAO "Evaluations" if they pertain to the Plan. Ignore "applied research" for now since we don't have a definition.

Once I get your submissions, I'll pull the pieces together and share back out to the Offices and the Lead Region before I ask the DAA for her review.

Also attached is OAR's guidance on developing the Strategic Plan.

Thanks in advance.

If you have any questions, please let me know.

Margaret

OCFO Memos etc. related to Strategic Plan and all things performance can be found at:
http://intranet.epa.gov/fmdvally/performance/performance_mgmt.htm

Margaret Walters, OAR Planning and State Grants Liaison

Office of Air and Radiation - U.S. Environmental Protection Agency

1200 Pennsylvania Ave NW | Washington, DC 20460-0001

202-564-4107 | walters.margaret@epa.gov

To: Irving, Bill[Irving.Bill@epa.gov]
From: EAS.System@epamail.epa.gov
Sent: Tue 6/18/2013 3:48:04 PM
Subject: EAS Document Notification: For your approval--Requisition: PR-OAR-13-01272

Requisition: PR-OAR-13-01272 is ready for your approval in EAS.

Description: The purpose of this memorandum is to request a technical and cost proposal from each contractor for the tasks outlined in the attached Statement of Work (SOW) entitled Greenhouse Gas Inventory and Analyses for Selected Agricultural and LULUCF Categories which outlines contractor support for developing greenhouse gas flux estimates for Rice, Agricultural Residue Burning, Soil Liming and Urea Application, and assist with developing the associated text and documentation for estimates of nitrous oxide emissions from Agricultural Soil Management, including soil nitrous oxide emissions from Settlements and Forestlands, soil carbon flux from Croplands and Grasslands and the section on Representation of the US Land Base for the Inventory of US Greenhouse Gas Emissions and Sinks: 1990-2012; and quick turnaround assignments related to work on the greenhouse gas flux categories listed above.

New Competitive Task Order Request for "Greenhouse Gas Inventory and Analyses for Selected Agricultural and LULUCF Categories" under EPA Contract EP-BPA-12-H-0021/22 (\$39,630 IGCE)

Owner: Tom Wirth

Requisitioner: Tom Wirth

Site: OAR/OAP

Issuing Office: HPOD

To: Irving, Bill[Irving.Bill@epa.gov]
From: Wirth, Tom
Sent: Thur 11/14/2013 8:47:26 PM
Subject: RE: Table 4(IV)

Bill,

Ex. 5 - Deliberative Process

Does that help, or did I just make it more confusing while also bringing up a bunch of new issues?

Tom Wirth
US Environmental Protection Agency
Climate Change Division

Tel: 202 343-9313
Mobile: 703 399-1594

Wirth.tom@epa.gov

-----Original Message-----

From: Irving, Bill
Sent: Thursday, November 14, 2013 1:49 PM
To: Wirth, Tom
Subject: Table 4(IV)

Tom

Can you provide additional context on your comment about breaking emissions out by land-use type? Is it something we need for indirects? Can we do it in the NIR?

To: Cindy Newberg; Ex. 6 - Personal Privacy Newberg, Cindy[Newberg.Cindy@epa.gov]
From: Marianne Hawker
Sent: Mon 11/4/2013 12:46:16 PM
Subject: File needed
DRAFT SNAP Status 102413-dsq mas RL cn.docx

Hi Cindy
Attached is the file you needed.

Marianne

To: Newberg, Cindy[Newberg.Cindy@epa.gov]
From: Thompson, John E
Sent: Thur 10/31/2013 7:05:58 PM
Subject: FW: For EO 12866/13563 Review -- Protection of Stratospheric Ozone: Adjustments to the Allowance System for Controlling HCFC Production, Import, and Export for 2015-2019
[EPA response to Interagency Comments under EO12866_13563HCFC Allocation rule_10 24 13.docx](#)

From: Frey, Nathan J. Ex. 6 - Personal Privacy
Sent: Thursday, October 31, 2013 3:05 PM
To: San Martini, Federico M; Thompson, John E; 'gc-71energyregs@hq.doe.gov' (gc-71energyregs@hq.doe.gov); 'elizabeth.kohl@hq.doe.gov'; 'felix.mestey@navy.mil'; 'Rostker, David J.' (David.Rostker@sba.gov); 'Kymn, Christine J. (Christine.Kymn@sba.gov)'
Subject: RE: For EO 12866/13563 Review -- Protection of Stratospheric Ozone: Adjustments to the Allowance System for Controlling HCFC Production, Import, and Export for 2015-2019

Attached please find EPA responses to interagency comments. Please let me know by **COB Monday, November 4th** if there are any outstanding issues that your agency would like to discuss with EPA.

Thanks and please let me know if you have any questions.

From: Frey, Nathan J.
Sent: Thursday, August 29, 2013 5:45 PM
To: 'San Martini, Federico M'; Thompson, John E (OES) (ThompsonJE2@state.gov); 'gc-71energyregs@hq.doe.gov' (gc-71energyregs@hq.doe.gov); 'elizabeth.kohl@hq.doe.gov'; 'felix.mestey@navy.mil'; 'Rostker, David J.' (David.Rostker@sba.gov); Kymn, Christine J. (Christine.Kymn@sba.gov)
Subject: For EO 12866/13563 Review -- Protection of Stratospheric Ozone: Adjustments to the Allowance System for Controlling HCFC Production, Import, and Export for 2015-2019

Attached for your review and comment please find the EPA proposed rule entitled, Protection of Stratospheric Ozone: Adjustments to the Allowance System for Controlling

HCFC Production, Import and Export for 2015-2019.

SUMMARY: EPA is seeking comment on options for adjusting the allowance system controlling U.S. consumption and production of hydrochlorofluorocarbons (HCFCs).

Ex. 5 - Deliberative Process

Reminder: Under the governing EOs, these documents are provided for review by Federal executive branch agencies only, and should not be distributed further. Please also recall the docketing requirements under the Clean Air Act. I'm happy to provide guidance if anyone has questions about the EOs 12866 and 13563 process.

Please provide any comments on the rule by **COB Friday, September 13th**.

If you need more time or have any questions, please let me know.

Nathan Frey

Office of Information and Regulatory Affairs

Ex. 6 - Personal Privacy

From: Maranion, Bella
Location: call
Importance: Normal
Subject: Discuss initial OGC SCR rule comments and response to Diane
Start Date/Time: Tue 12/17/2013 1:00:00 PM
End Date/Time: Tue 12/17/2013 1:30:00 PM
some initial comments: draft SNAP Status Change proposed rule

Cindy,
I'm reviewing the comments from Diane and Jan now, but wanted to carve out some time with you to discuss and see how you'd like to proceed with OGC.

Thanks,
Bella

From: McConkey, Diane
Sent: Monday, December 16, 2013 4:27 PM
To: Maranion, Bella; Tierney, Jan
Cc: Newberg, Cindy; Sheppard, Margaret
Subject: some initial comments: draft SNAP Status Change proposed rule
Attachments: DRAFT_SNAP_Status_Change_Rule_112613_CLEAN
jmt_dem.page.60.docx

Hi Bella,

Here are initial line-by-line OGC comments on the Status Change rule. Please consider these together with the more general comments we provided earlier.

Ex. 5 - Deliberative Process

Is someone working on a SBREFA screening analysis for this rule? I thought I had heard that mentioned.

We both had significant comments on the HCFC section. I suggest we talk about that section before you do any extensive revisions.

Ex. 5 - Deliberative Process

Thanks,

Diane

From: Maranion, Bella

Sent: Tuesday, November 26, 2013 4:51 PM

To: Tierney, Jan; McConkey, Diane

Cc: Newberg, Cindy; Sheppard, Margaret

Subject: Review of abstract and draft SNAP Status Change proposed rule

Dear Jan and Diane,

First, I wanted to ask for your quick review of the draft abstract language, below, which we intend to use in ADP Tracker for the SNAP proposed rule to change the status of alternatives previously found acceptable in specific end-uses in various sectors:

Ex. 5 - Deliberative Process

Please let me know by **COB Monday December 2** if you have any concerns with the above draft text so we can complete our rule entry in ADP Tracker.

For your additional review, please find attached the draft proposed rule. In some cases, we are writing restrictions to the use of certain substitutes and, in other cases, we are finding the substitutes unacceptable. The rule would also propose to change the status of certain HCFCs consistent with the §605(a) rule. In this draft, please note the following:

- We continue to work through a few additional decisions, particularly in commercial refrigeration and retrofit options, and we tried to flag these for you.
- Comments are included where the context may be useful for OGC; we've also highlighted in the comment boxes some issues for which we are seeking specific OGC advice.
- We generally indicated in the document where additional work is continuing so that language may be included in the next draft.

I would appreciate if you could get me your comments on this draft by **COB, Monday, December 16**.

Thanks very much for your assistance,

Bella

Bella A. Maranion

Alternatives & Emissions Reduction Branch

Stratospheric Protection Division (M/C 6205J)

Office of Air & Radiation, Office of Atmospheric Programs

Washington, DC

Office: +1 202 343 9749

Cell: +1 202 257-7922

<mailto:maranion.bella@epa.gov>

To: Maranion, Bella[Maranion.Bella@epa.gov]; Landolfi, Robert[Landolfi.Robert@epa.gov]
Cc: Sheppard, Margaret[Sheppard.Margaret@epa.gov]; Newberg, Cindy[Newberg.Cindy@epa.gov]
From: Godwin, Dave
Sent: Sat 9/28/2013 2:42:17 AM
Subject: RE: DRAFT SNAP Status Change Rule
DRAFT SNAP Status 091913-dsg.docx

Thanks, I'm relinquishing the pen! Added several pages mainly in the commercial refrigeration section reflecting what I think we decided upon last week.

I know Rob has been reviewing in parallel but hopefully our comments don't overlap (I don't think I added any new edits or comments to the science section).

Two main points that I think we still need to discuss

Ex. 5 - Deliberative Process

From: Maranion, Bella
Sent: Tuesday, September 24, 2013 12:50 PM
To: Godwin, Dave; Landolfi, Robert
Cc: Sheppard, Margaret; Newberg, Cindy
Subject: FW: DRAFT SNAP Status Change Rule

Dave – please find the last version of the marked up draft rule which I sent out last week before our meeting, so doesn't yet reflect that discussion. So I have you holding the pen on the draft version for now.

Margaret – you can take a look but maybe wait to get Dave's changes to add yours so we can keep version control.

Rob – FYI the science discussion that needs work starts at the bottom of page 13 through page

15. I thought having the draft rule context would be helpful to your work on this section. I suggest that you re-draft this section on a separate track/document and we can drop into the next revised draft of this rule at some point, just to help with version control.

Thanks,

Bella

From: Maranion, Bella
Sent: Thursday, September 19, 2013 9:42 AM
To: Newberg, Cindy
Cc: Godwin, Dave; Sheppard, Margaret
Subject: DRAFT SNAP Status Change Rule

Cindy,

Please find attached the latest draft of the Status Change rule with Dave's and Margaret's edits and comments. This will need your review and further discussion. I thought that at our meeting today, we could highlight and discuss some of the key questions/issues in the sectors, as well as overall status.

For the overall discussion, I am also attaching the update that Dave presented at T6 last week, plus the rules timeline table that we've reviewed previously in T6.

Thanks,

Bella

To: Newberg, Cindy[Newberg.Cindy@epa.gov]
Cc: Maranion, Bella[Maranion.Bella@epa.gov]
From: Horwitz, Paul
Sent: Wed 5/22/2013 10:41:54 AM
Subject: Delist framing document
[delist framing-paul4.doc](#)

Hi Cindy and Bella – attached are some more thoughts on the preamble. I hope some of the language or ideas are useful.

Paul

From: Newberg, Cindy
Sent: Tuesday, May 21, 2013 1:01 PM
To: Fiffer, Melissa; Horwitz, Paul; Sheppard, Margaret
Subject: RE: Mtg today on TSCA early stages on nPB

Thanks Melissa. A quick read out will be helpful, and think of it as a leg up (!) on the Bird-Dog request I am planning to send out later today.

Cindy Newberg

+1 202 343 9729

From: Fiffer, Melissa
Sent: Tuesday, May 21, 2013 11:57 AM
To: Newberg, Cindy; Horwitz, Paul; Sheppard, Margaret
Subject: Mtg today on TSCA early stages on nPB

Hi,

Update: OCSPP has asked me to attend an internal, staff-level meeting this afternoon at EPA East with their hazard and exposure staff who will be initiating the nPB look-back evaluation.

They want me to provide an overview of what we've done under SNAP – I'll just work from the docs we all reviewed a few months ago, including the reg history document. I understand that they also have someone speaking about work being done on dry cleaning alternatives.

I'll let you know what I learn.

Thanks,

Melissa

Melissa Fiffer

Stratospheric Protection Division

U.S. Environmental Protection Agency

Office: (202) 343-9464

Mobile: (202) 500-3531

Fiffer.Melissa@epa.gov

From: Fiffer, Melissa

Sent: Tuesday, May 14, 2013 2:13 PM

To: Sheppard, Margaret; Newberg, Cindy; Horwitz, Paul

Subject: RE: TSCA early stages on nPB

P.S. – I was able to glean some more details about the TSCA review process for nPB. Their intent is to prepare focused risk assessments on 1-2 end uses of nPB (likely including dry cleaning and adhesives or aerosols) and put it out for public comment in summer 2014. To develop the documents they will run a workgroup including other EPA offices as well as representatives from NIOSH and OSHA. I asked to be added to the workgroup invite.

Thanks,

Melissa

Melissa Fiffer

Stratospheric Protection Division

U.S. Environmental Protection Agency

Office: (202) 343-9464

Mobile: (202) 500-3531

Fiffer.Melissa@epa.gov

From: Fiffer, Melissa

Sent: Tuesday, May 14, 2013 10:46 AM

To: Sheppard, Margaret; Newberg, Cindy; Horwitz, Paul

Subject: TSCA early stages on nPB

Hi folks,

Just wanted to let you know that I received a call this morning from Sharon Oxendine in the TSCA office, Risk Assessment Division, Existing Chemicals Assessment Branch. She has asked me to send over information on how the SNAP program evaluated each of the nPB end uses (i.e., info from our risk screens that supported our proposed/final rules). They are having a preliminary internal TSCA meeting tomorrow to get folks up to speed. This is part of the look-back process we saw an announcement about on March 27 –

TSCA included nPB in an announcement of 7 chemicals it will conduct a risk assessment on in 2013:

<http://yosemite.epa.gov/opa/admpress.nsf/bd4379a92ceceecac8525735900400c27/c6be79994c3fd08785257b3b0054e2fa!>

Thanks,

Melissa

internal and deliberative – do not cite or quote

Melissa Fiffer

Stratospheric Protection Division

U.S. Environmental Protection Agency

Office: (202) 343-9464

Mobile: (202) 500-3531

Fiffer.Melissa@epa.gov

To: Newberg, Cindy[Newberg.Cindy@epa.gov]
From: Maranion, Bella
Sent: Thur 4/18/2013 3:16:52 PM
Subject: RE: next draft
[delist framing-rev2-BM.docx](#)

Cindy,

Thanks for this. I think the general background is all there - reviewed primarily to see if the flow of background info and context made sense. Please find attached my comments/edits and happy to discuss more.

Thanks,

Bella

From: Newberg, Cindy
Sent: Thursday, April 18, 2013 8:48 AM
To: Maranion, Bella
Subject: next draft

Okay, see what you think. Still rough but maybe all the general background is there – sorta.

Cindy Newberg, Chief

Alternatives and Emissions Reduction Branch

Office of Atmospheric Programs

Office of Air and Radiation

U.S. Environmental Protection Agency

+1 202 343 9729

To: Godwin, Dave[Godwin.Dave@epa.gov]
Cc: Newberg, Cindy[Newberg.Cindy@epa.gov]
From: Sheppard, Margaret
Sent: Tue 8/6/2013 10:26:44 PM
Subject: detailed comments on drafty delisting rule
[delist framing-Aug 6 ms comm.docx](#)

Dave,
I'm passing on my detailed comments on the delisting rule so that you can get started when you're done with the flammable refrigerants rule. (How's that going?)

Cindy,

Ex. 5 - Deliberative Process

You've put together a lot of great ideas and have the basic framing in place. Thank you for your hard work on this!

Margaret Sheppard
Environmental Scientist
Significant New Alternatives Policy (SNAP) Program
US EPA/Stratospheric Protection Division
Tel. 202-343-9163
Fax 202-343-2338
Email sheppard.margaret@epa.gov

To: Newberg, Cindy[Newberg.Cindy@epa.gov]
From: Maranion, Bella
Sent: Wed 4/17/2013 3:01:06 AM
Subject: RE: very rough draft
[delist framing-BM.docx](#)

My very rough initial edits – hope these are helpful. I think the overall concepts to frame the rule are all in there so nice start!

Bella

From: Newberg, Cindy
Sent: Tuesday, April 16, 2013 3:56 PM
To: Maranion, Bella
Subject: very rough draft

Cindy Newberg, Chief

Alternatives and Emissions Reduction Branch

Office of Atmospheric Programs

Office of Air and Radiation

U.S. Environmental Protection Agency

+1 202 343 9729

To: thompsonje2@state.gov[thompsonje2@state.gov]; Newberg, Cindy[Newberg.Cindy@epa.gov]
Cc: Todd Stern (sterntd@state.gov)[sterntd@state.gov]; Reifsnyder, Daniel A (OES)[ReifsnyderDA@state.gov]; Schmidt, Jake[jschmidt@nrdc.org]; Lin, Alvin[alin@nrdc-china.org]
From: Doniger, David
Sent: Tue 7/9/2013 9:40:36 PM
Subject: HFCs in China -- Research by HU Jiamin from Peking U.
[HU Jianxin F-Gases Management in China.pdf](#)
[Peking Univ F-Gas Study 2013.pdf](#)

Attached are slides and a paper on HFC reduction options in China, by HU Jiamin, professor at Peking U., who has long advised China's MEP on Montreal Protocol issues, and sometimes been on the TEAP and on their delegation, I believe.

The paper is a thoughtful effort to project BAU HFC growth, assess alternatives focusing on two key areas (mobile and room air conditioning) plus HFC-23 destruction, and examine the economics. (The slides get to HFCs starting on slide 24.) Though funded by an outside source, the Energy Foundation's China branch, it has been written to serve an internal debate on policy options.

You can see the beginnings of a position on how much credit they should get in the future climate agreement if they agree to a Montreal Protocol phase-down. Gotta watch out for how BAU is calculated.

The paper also has the beginnings of an incremental cost analysis aimed at the Multilateral Fund and GEF.

David D. Doniger

Policy Director, Climate and Clean Air Program

Natural Resources Defense Council

1152 15th Street, NW, Suite 300

Washington, DC 20005

Phone: (202) 289-2403

Cell: (202) 321-3435

Fax: (202) 289-1060

ddoniger@nrdc.org

on the web at www.nrdc.org

read my blog: <http://switchboard.nrdc.org/blogs/ddoniger/>

To: Tierney, Jan[tierney.jan@epa.gov]; McConkey, Diane[Mcconkey.Diane@epa.gov]
Cc: Newberg, Cindy[Newberg.Cindy@epa.gov]; Sheppard, Margaret[Sheppard.Margaret@epa.gov]
From: Maranion, Bella
Sent: Tue 11/26/2013 9:50:54 PM
Subject: Review of abstract and draft SNAP Status Change proposed rule
[DRAFT SNAP Status Change Rule 112613 CLEAN.docx](#)

Dear Jan and Diane,

First, I wanted to ask for your quick review of the draft abstract language, below, which we intend to use in ADP Tracker for the SNAP proposed rule to change the status of alternatives previously found acceptable in specific end-uses in various sectors:

Ex. 5 - Deliberative Process

Please let me know by **COB Monday December 2** if you have any concerns with the above draft text so we can complete our rule entry in ADP Tracker.

For your additional review, please find attached the draft proposed rule. In some cases, we are

Ex. 5 - Deliberative Process

I would appreciate if you could get me your comments on this draft by **COB, Monday, December 16.**

Thanks very much for your assistance,

Bella

Bella A. Maranion

Alternatives & Emissions Reduction Branch

Stratospheric Protection Division (M/C 6205J)

Office of Air & Radiation, Office of Atmospheric Programs

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Office: +1 202 343 9749

Cell: +1 202 257-7922

<mailto:maranion.bella@epa.gov>

To: Maranion, Bella[Maranion.Bella@epa.gov]
Cc: Fiffer, Melissa[Fiffer.Melissa@epa.gov]; Rim, Elisa[Rim.Elisa@epa.gov]; Arling, Jeremy[Arling.Jeremy@epa.gov]; Sheppard, Margaret[Sheppard.Margaret@epa.gov]; VonDemHagen, Rebecca[VonDemHagen.Rebecca@epa.gov]; Landolfi, Robert[Landolfi.Robert@epa.gov]; Hamlin, Sally[Hamlin.Sally@epa.gov]; Godwin, Dave[Godwin.Dave@epa.gov]
From: Newberg, Cindy
Sent: Sun 11/24/2013 9:23:38 PM
Subject: Re: Review revised draft Status Change Rule
DRAFT SNAP Status 112313 CLEAN cn.docx

Thanks to everyone for all the work pulling this together. I went through the whole package again and I think it's in good shape(!) and can go to OGC for a first read recognizing that we still have a great deal of work to do over the next few weeks. Bella, I put in few redline/strikeout and addressed some of the comments. Also, I would like to chat with you about what you're putting in the cover note. I think this needs to go to Jan and Diane -- but probably not Sonja and Melina. I assume Diane will add them in if she thinks they need review it.

Ex. 5 - Deliberative Process

From: Maranion, Bella
Sent: Sunday, November 24, 2013 12:59:43 AM
To: Newberg, Cindy
Cc: Fiffer, Melissa; Rim, Elisa; Arling, Jeremy; Sheppard, Margaret; VonDemHagen, Rebecca; Landolfi, Robert; Hamlin, Sally; Godwin, Dave
Subject: RE: Review revised draft Status Change Rule

Cindy,

Tag! Here's the CLEAN revised draft version of the rule for your review. We kept some comments in to help provide the context for changes and where there is an issue or question that still needs to be resolved/discussed, and we'll need to decide which comments remain in the version for OGC.

Thanks,

Bella

From: Godwin, Dave
Sent: Friday, November 22, 2013 10:29 PM
To: Maranion, Bella
Cc: Fiffer, Melissa; Rim, Elisa; Arling, Jeremy; Newberg, Cindy; Sheppard, Margaret; VonDemHagen, Rebecca; Landolfi, Robert; Hamlin, Sally
Subject: RE: Review revised draft Status Change Rule

Bella, I forgot to give you the official pen before you left.

Here are my edits that we discussed. I hope I copied our table of proposals and fall-backs correctly.

Ex. 5 - Deliberative Process

Ex. 5 - Deliberative Process

From: Maranion, Bella
Sent: Tuesday, November 19, 2013 5:31 PM
To: Newberg, Cindy; Sheppard, Margaret; Godwin, Dave; VonDemHagen, Rebecca; Landolfi, Robert; Hamlin, Sally
Cc: Fiffer, Melissa; Rim, Elisa; Arling, Jeremy
Subject: Review revised draft Status Change Rule
Importance: High

Dear Status Change Rule Team,

Please find attached the latest draft of the rule (thanks again to Dave and Margaret for further review and revisions). PLEASE DO NOT EDIT THIS DRAFT. It would be helpful if you could review this draft so we can go through and discuss edits, comments, outstanding questions in our meeting tomorrow.

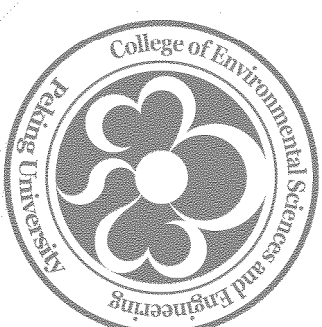
Margaret also helpfully provided a list of some of her questions which I've also attached for your information. She highlighted some of her bigger questions as below:

Ex. 5 - Deliberative Process

Look forward to going through this with you tomorrow.

Thanks,

Bella



HFC Management in China: Challenges & Opportunities

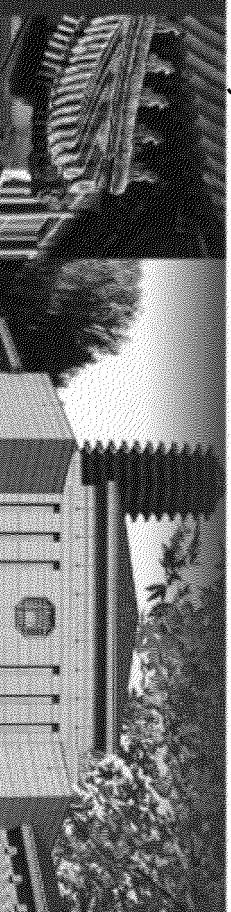
Jianxin Hu

College of Environmental Sciences & Engineering, PKU

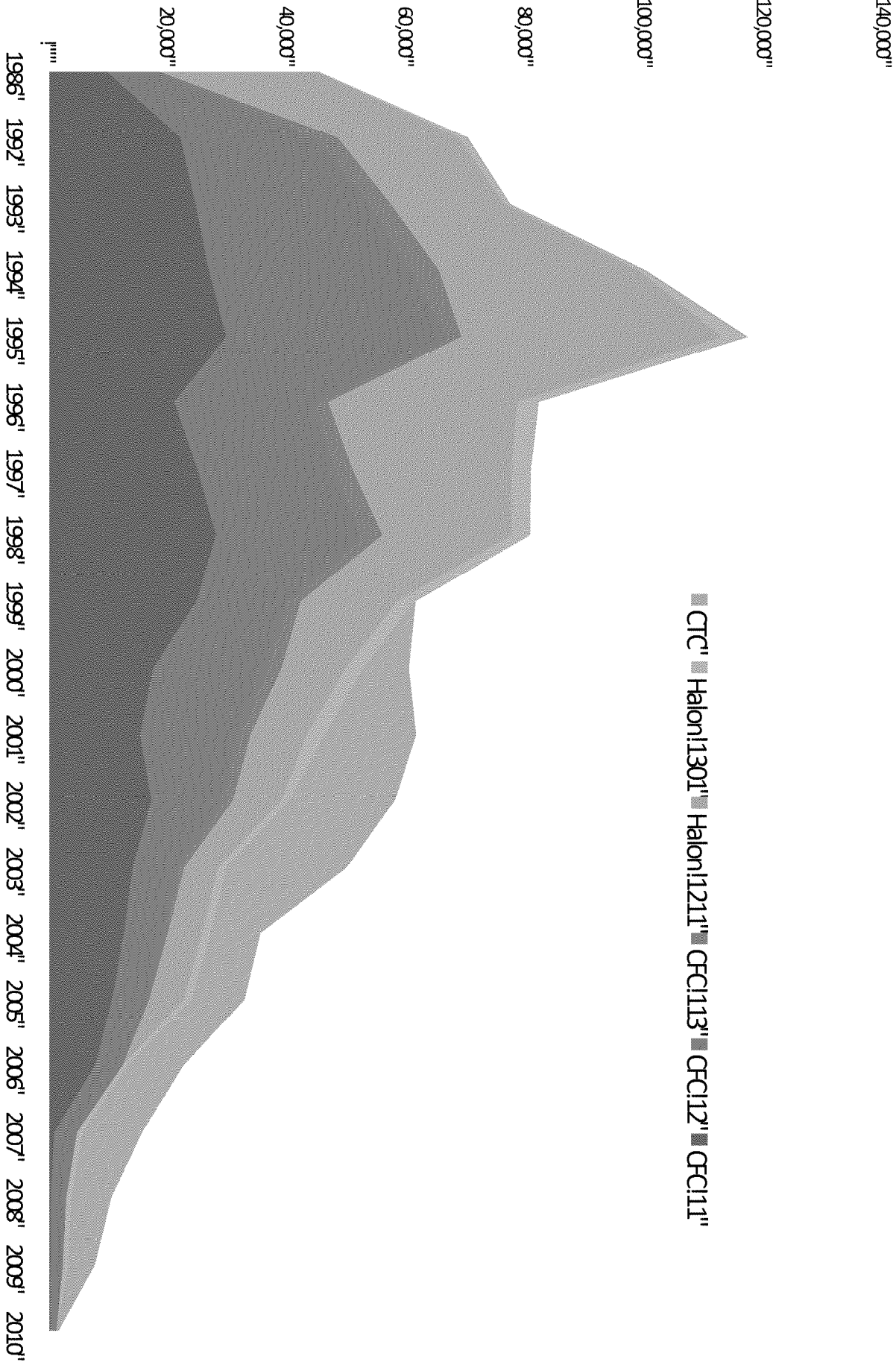
Dubrovnik, June 20, 2013



北京大学



Main ODS consumption in China



Overall benefits for 2010

	NMP87	Offsets	Net value
	-Baseline		
		Ozone depletion	HFCs
GWP-weighted emissions (GtCO ₂ -eq/yr)	13.3-16.7	2.7-3.3	0.9
			9.7-12.5
Radiative forcing (W/m ²)	0.28-0.33	0.06	0.02
			0.20-0.25

- Kyoto target 2008-2012: ~2 GtCO₂-eq/yr

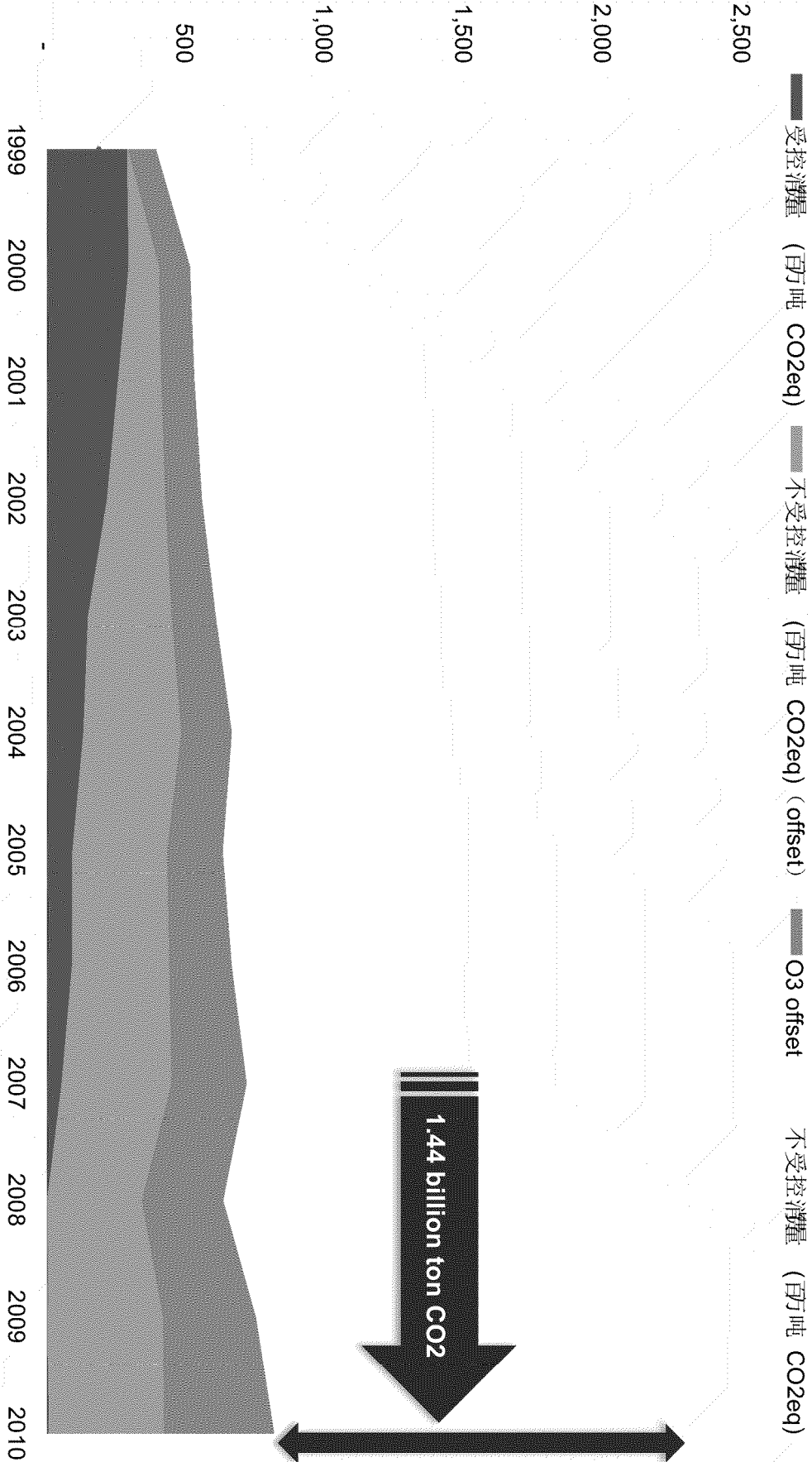
Velders, The importance of the Montreal Protocol in protecting climate, PNAS

Benefits calculation

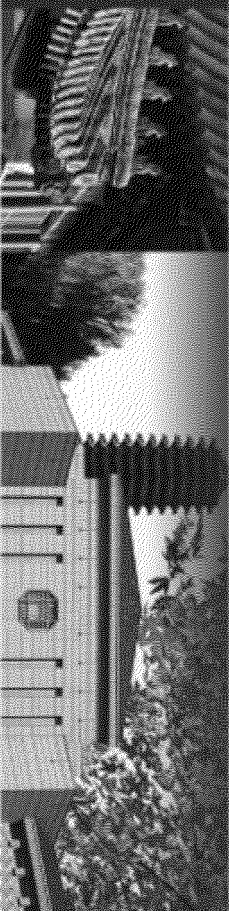
*ODP = Consumption under without
MP (k) - Real consumption (k)*

*GWVP = Consumption under
without MP - Real consumption –
offset HCFCS/HFCS – offset of O₃*

Benefit for climate (CFCs only)



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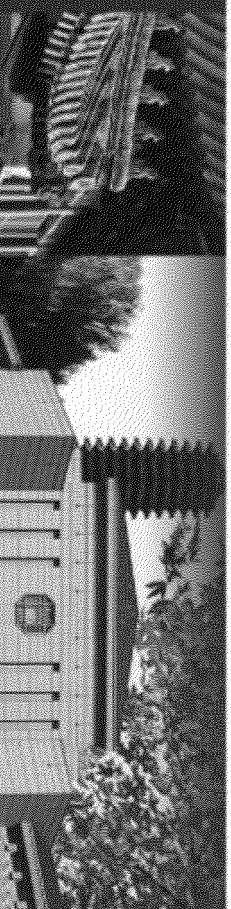
Co-benefits

Gained some other pollutants emission reduction, such as SO₂ and NO_x.

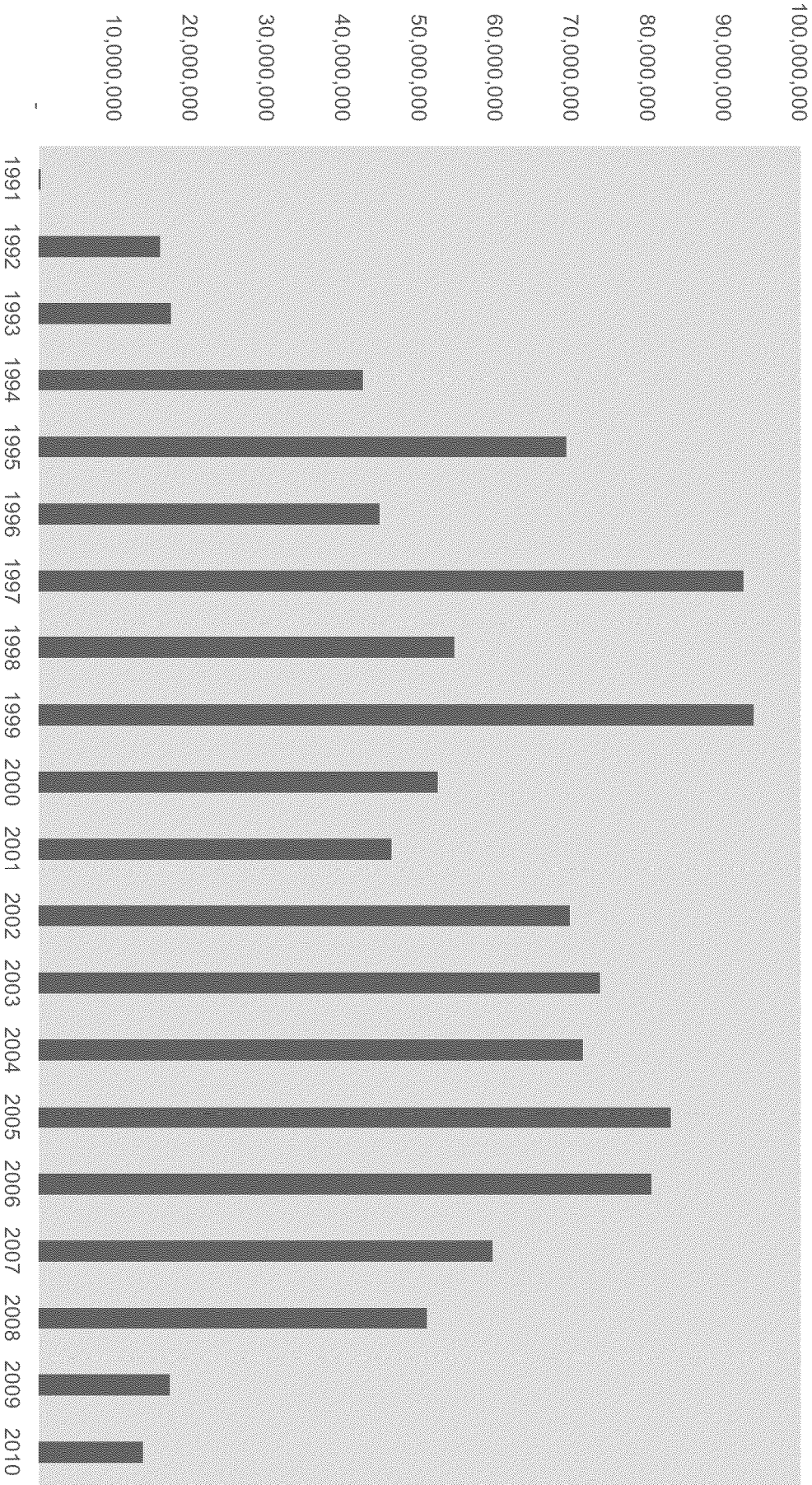
2 years before MP requirement phaseout CFCs and Halon (before the Beijing Olympic Game)



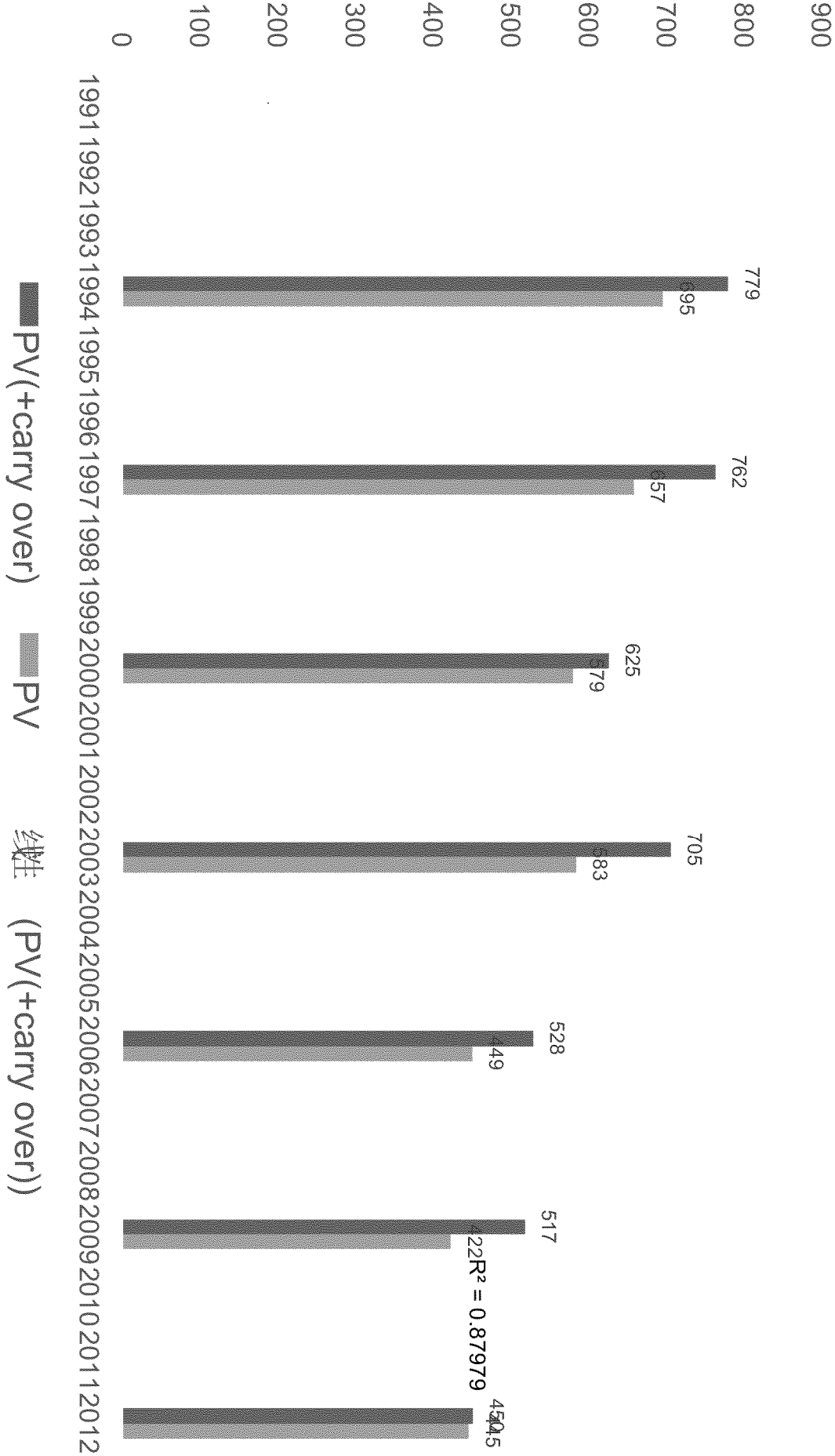
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MLF support for CFC/Halon Phaseout (price in 2012)



Replenishment of MLF (2012 price)

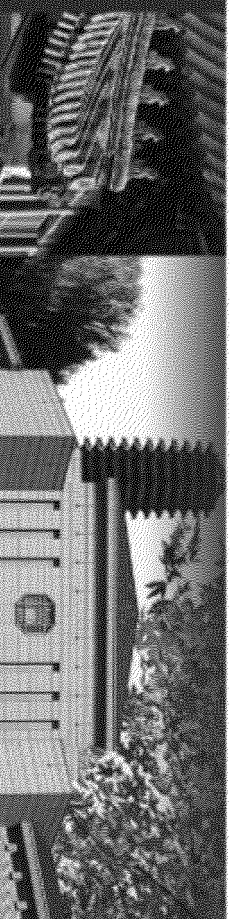


Promoting China's environment protection

- China's environment protection started relatively late.
- *Montreal Protocol* introduced some advanced technology, regulations, and management tool which enable China to improve environmental law system, enhance management level and promoting the environmental scientific technology development in the process of implementing international convention



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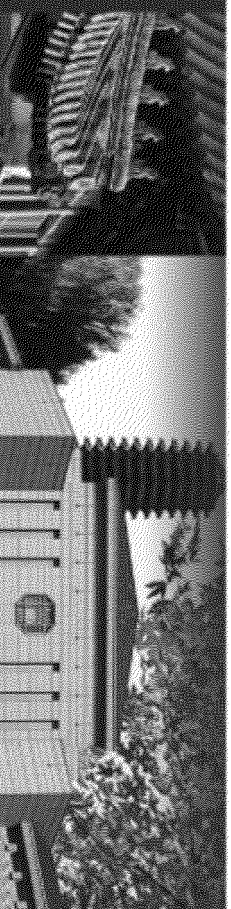


Country Program and its coordination mechanism

- Chinese government ratified *Country Program for phasing out ODS in China* in 1993. This is the first national plan in developing countries, based on which Chinese government established the governmental coordination mechanism and launching the phasing out step widely.
- All other environmental treats adopted the same approach such as UNFCCC, POPs and biodiversity in China.



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Establishment of laws and regulations

- China revised and published the *Law of*

Prevention and Control of Atmospheric

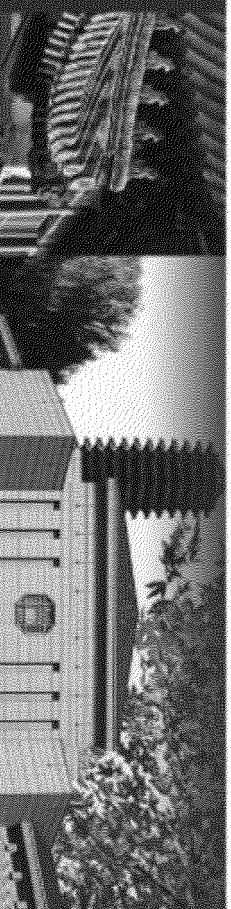
Pollution in 2000, which for the first time included two articles about ozone protection.

Based on *international laws* and *Atmospheric law*, the State Council published the *ODS Management Regulations* in 2010.

- First life cycle management on chemicals in China



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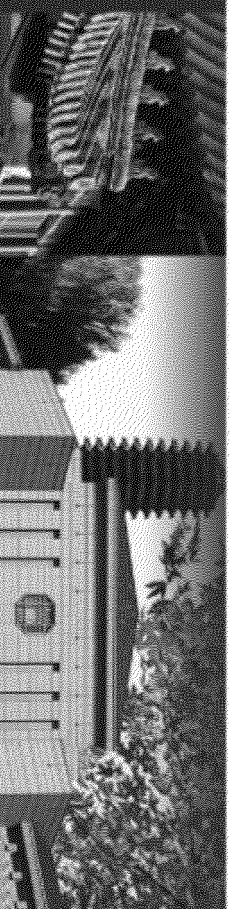


Institutional innovation

- China had established ODS *Tradable production quota system* in 1997 and *ODS import and export management system* in 1999 as its early introduced management systems of chemical pollutants, which are still in use after the *Administrative Permission Law* published in 2004. Lessons for SO₂, CO₂ and other trading policies, and other chemical management



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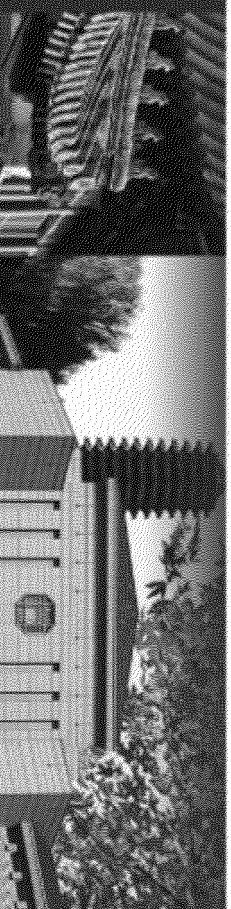


Organization capacity enhancement

- In order to implement ozone layer protection, China set up national ozone layer protection leading crew, Ozone protection Multilateral Fund project management Office, Task force in charge of implementing corresponding industry plans and umbrella projects, local EPAs, local industry department in charge and industry associations.
- In the past 20 years, over thousands of officials, technicians and individuals from enterprises participated the investigations and trainings held by international society, offering valuable chances to learn environmental protection experience from advanced countries and use it to serve our own career.



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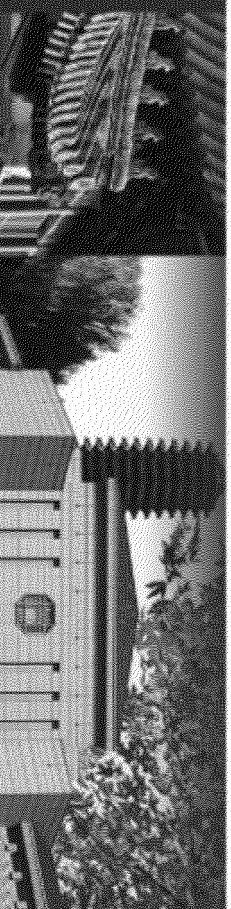


Local capacity enhancement

- Using the Multilateral Fund, China promoted the ozone layer protection capacity enhancement program in all provinces, improving local capacity as well as educating the public about on ozone layer protection.
- Better available information to public



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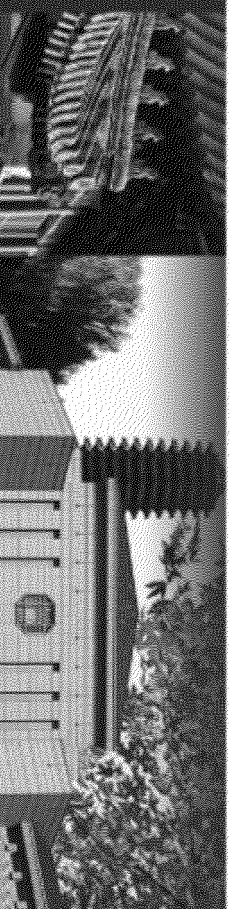


Promoting China's international status (diplomacy)

- China finished the country plan for ODS phasing out, China firstly phase out ODS using the sector mechanism which enabled us to finish the phasing out of CFCs and halogens two years before the convention, China finished 60% (ODP term) the phasing out task of all the developing countries,
- in 2004, China firstly researched the phasing out strategy of HCFs and played a leading role in the accelerated phasing out negotiation in 2007 (quoted from Canadian Minister of Environment).



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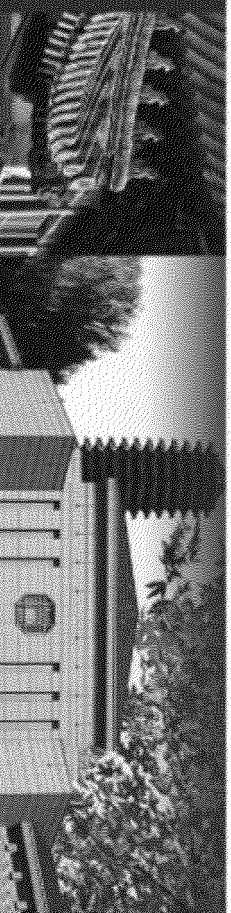


Incremental cost and alternatives

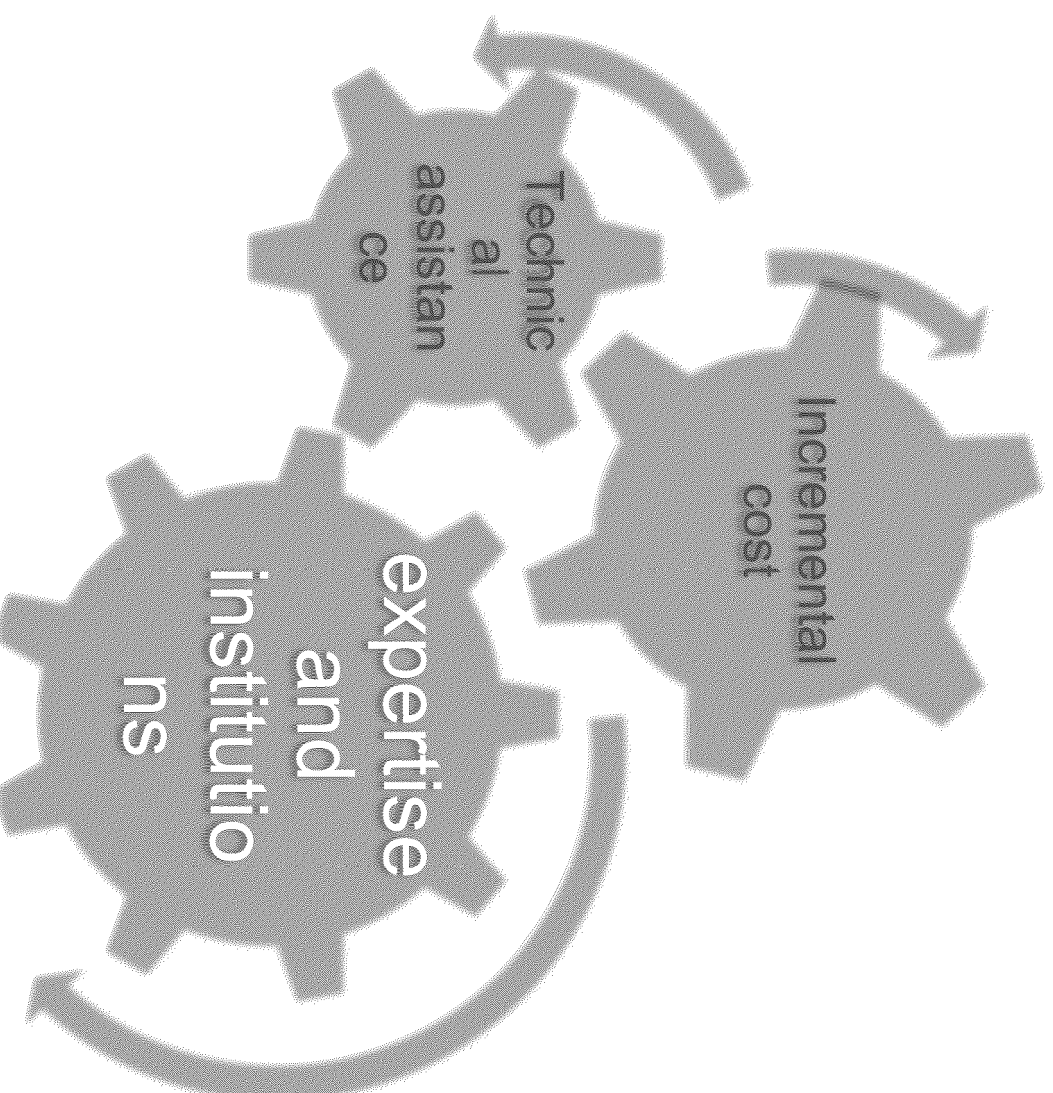
- Under the support of multilateral fund, China improved technology of the relative industry.
- All the native enterprises manufacturing refrigerators received multilateral fund, so for the time being they all adopt the environmental friendly HC technology in producing, by the way, China is the biggest refrigerator manufacturing country.



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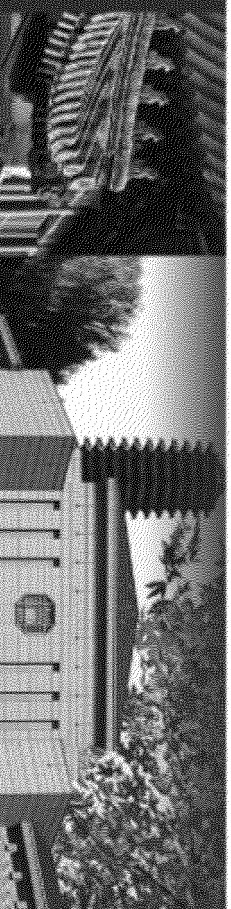
One of most important achievements
-----Successful mechanism for ODS phaseout
could benefit on phaseout of HCFCs and HFCs



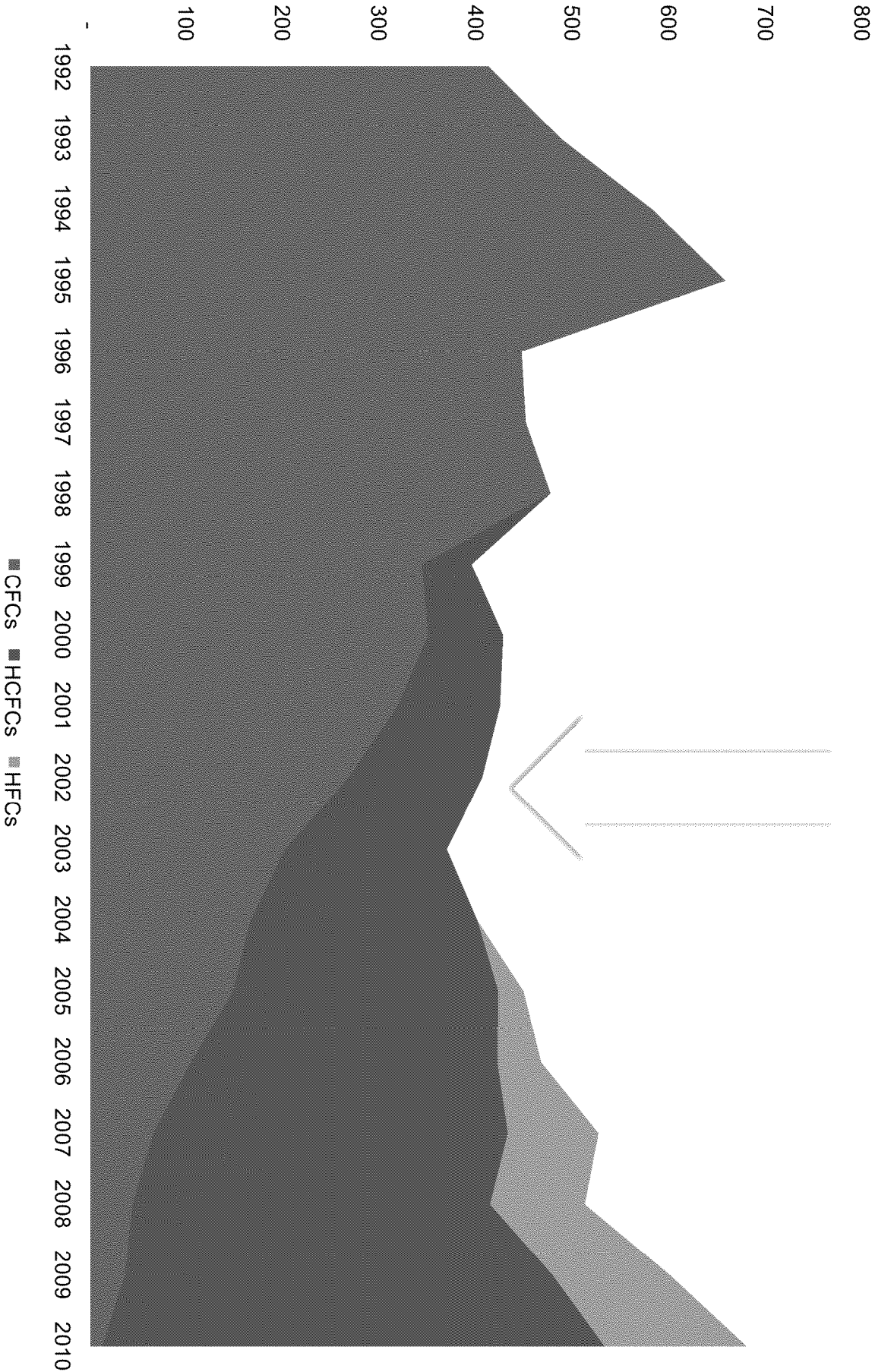
HCFC STORY 2004-2013



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Consumption of CFCs/HCFs/HFCs (Mt CO₂eq) (PKU report 2002)



Study on the Strategy for the Long Term Management of HFCs in China

College of Environmental Sciences, Peking University

CPR/EE/43/TAS/414

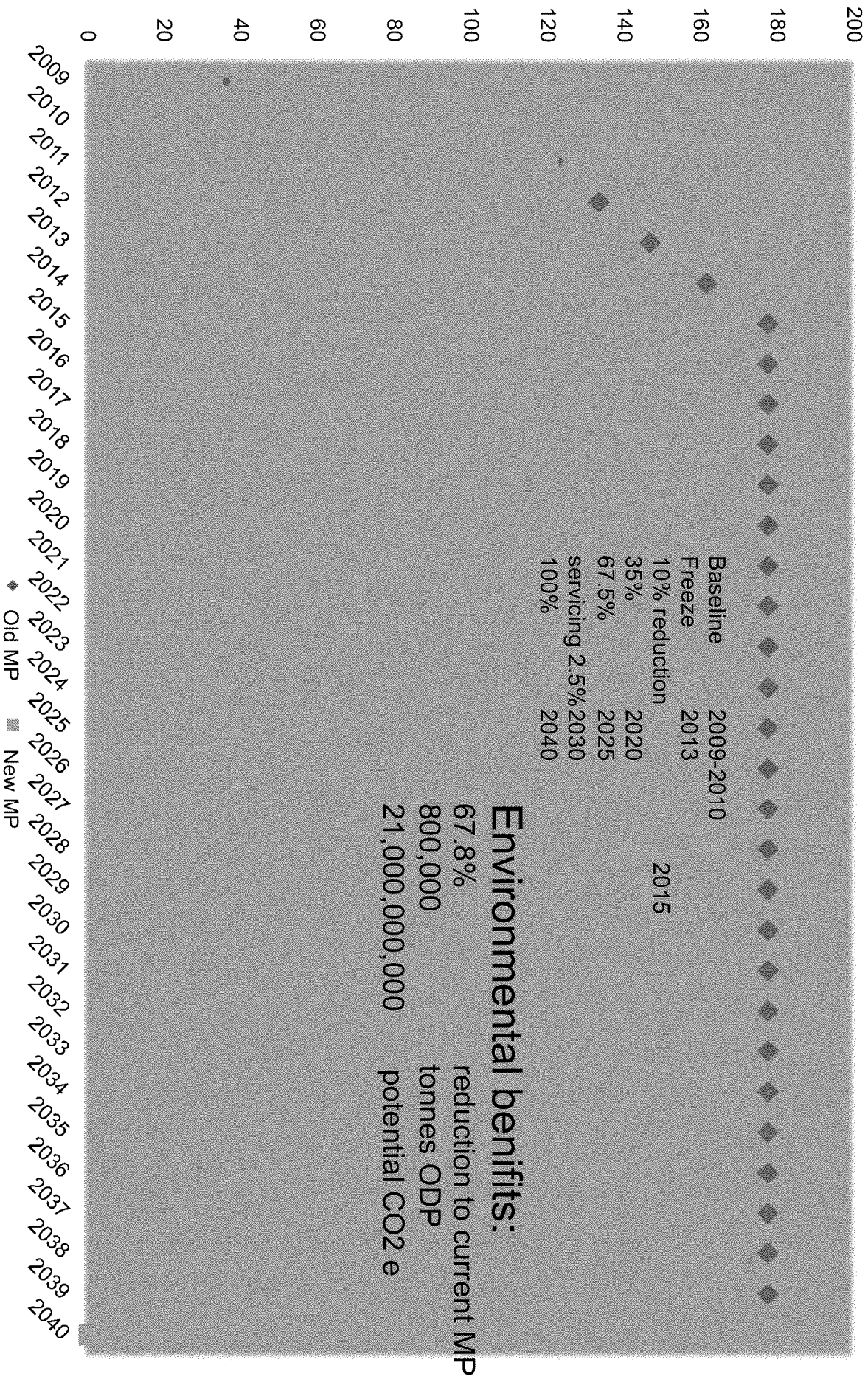
**funded under the Germilateral contribution
to the Multilateral Fund of the Montreal Protocol**

Submitted to the

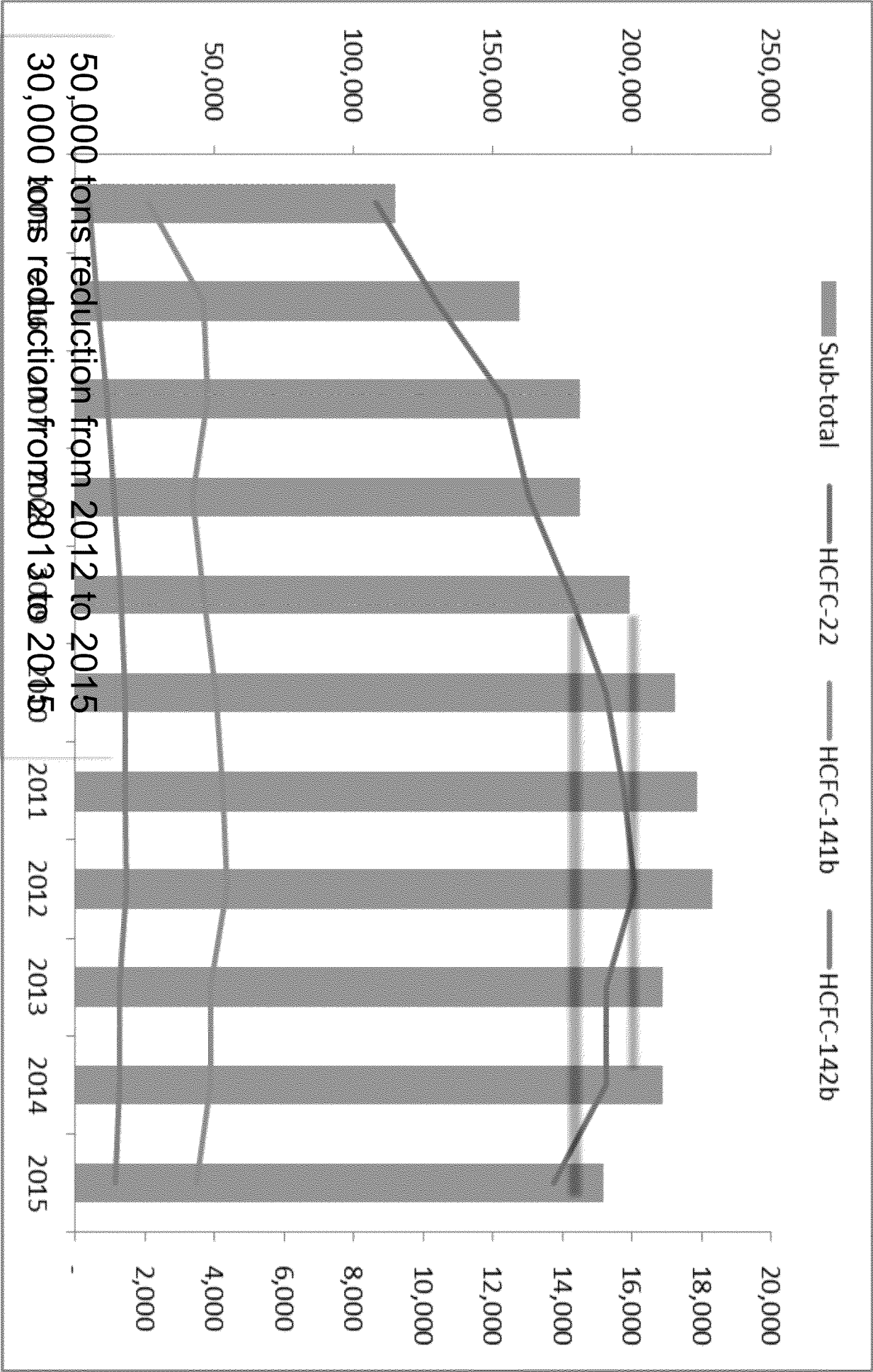
5th Meeting of the Executive Committee of the Multilateral Fund

8th February 2007

Accelerated phaseout of HCFCs



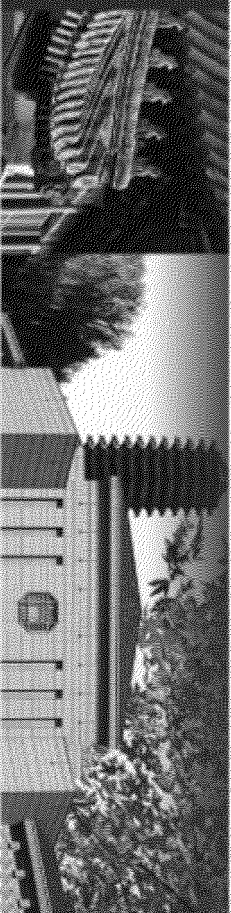
Historic and projected consumption HCFCs



WHAT IS NEXT FOR CHINA?



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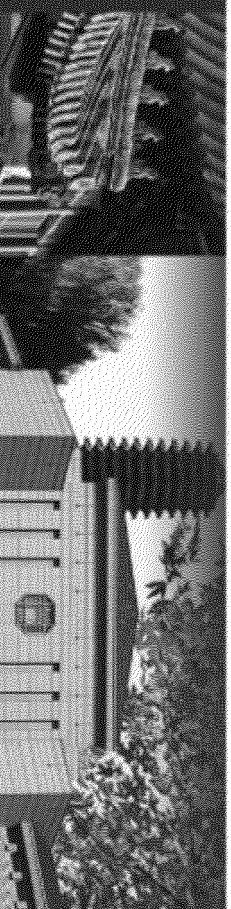


Objective

- The overall objective of this project is to provide scenario analysis for HFCs emission control, based on scenario analysis.
- 2012 The Energy Foundation project
Beijing Office



清华大学



Obama, Xi agree to cooperate on phasing down HFC usage

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U.S. News

Obama, Xi agree to cooperate on phasing down HFC usage

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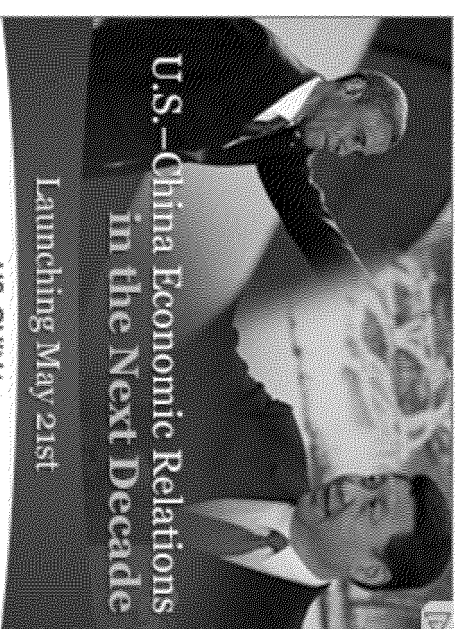
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Published: June 8, 2013 at 3:58 PM

LOS ANGELES, June 8 (UPI) -- President Barack Obama and Chinese President Xi Jinping have agreed on a plan to cut "consumption and production of hydrofluorocarbons," the White House said.

In an announcement issued as the two leaders met in California, the White House said the two leaders "have agreed on an important new step to confront global climate change."

"For the first time, the United States and China will work together and with other countries to use the expertise and institutions of the Montreal Protocol to phase down the consumption and production of hydrofluorocarbons (HFCs), among other forms of multilateral cooperation."



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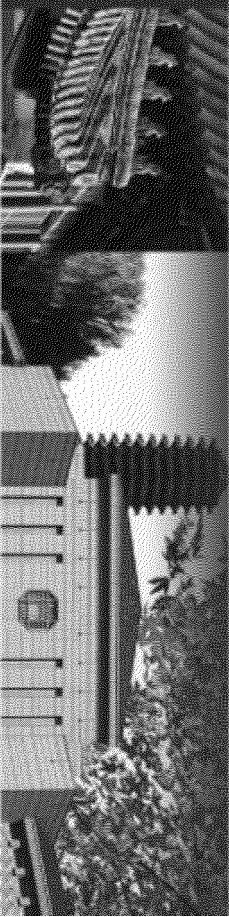
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Main applications of HFCs in China

HFC-134a	HFC-125&HFC32	HFC-245fa	HFC-152a	HFC-227ea
Automotive air conditioning refrigerant	Residential air conditioner refrigerant	Foaming agent	Refrigerant in refrigeration equipment	fire extinguishing agent
Refrigerant in refrigeration equipment	Refrigerant in refrigeration equipment	Solvent	Foamingagent	
Medical aerosol				
Others (foaming)		others		



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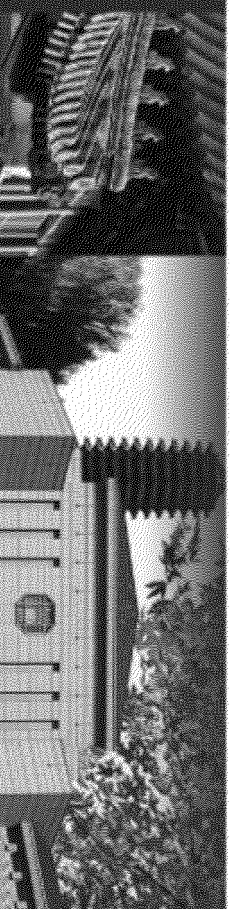
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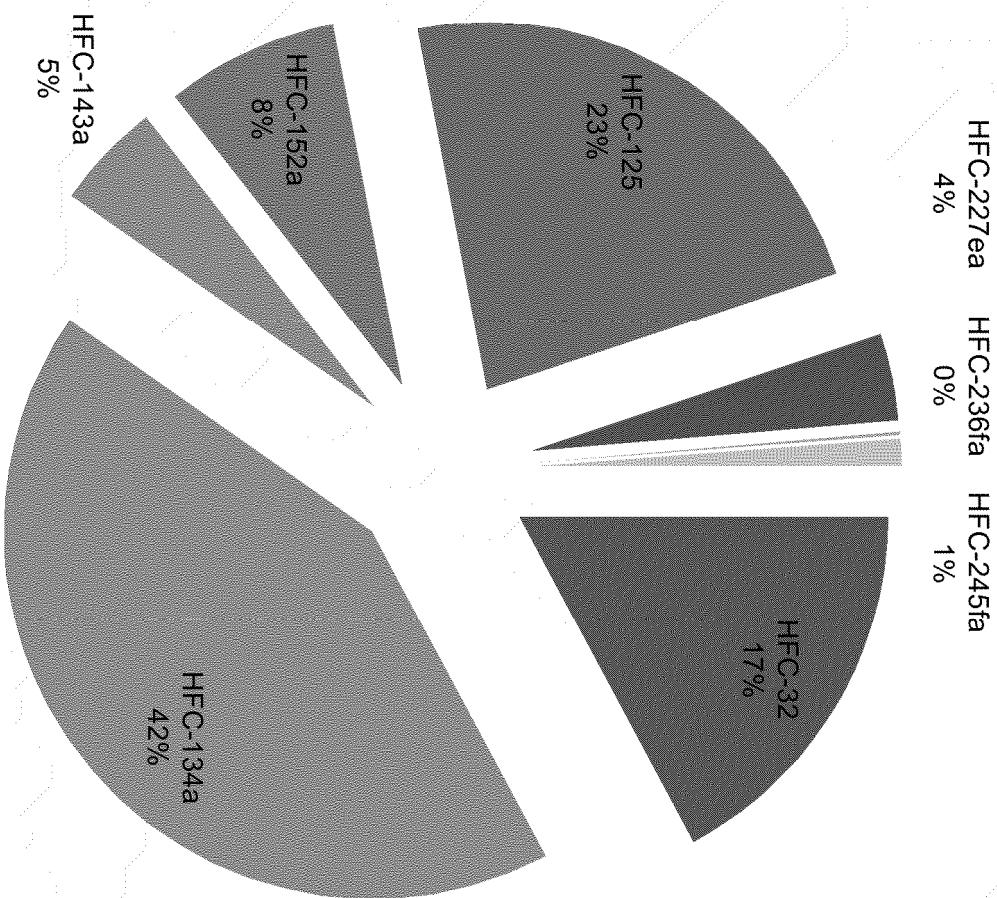
scenario analysis
2013-2050



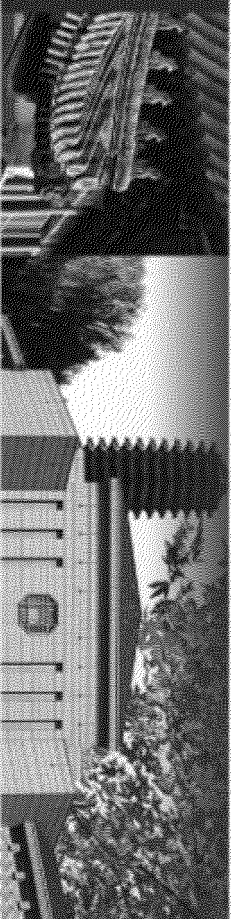
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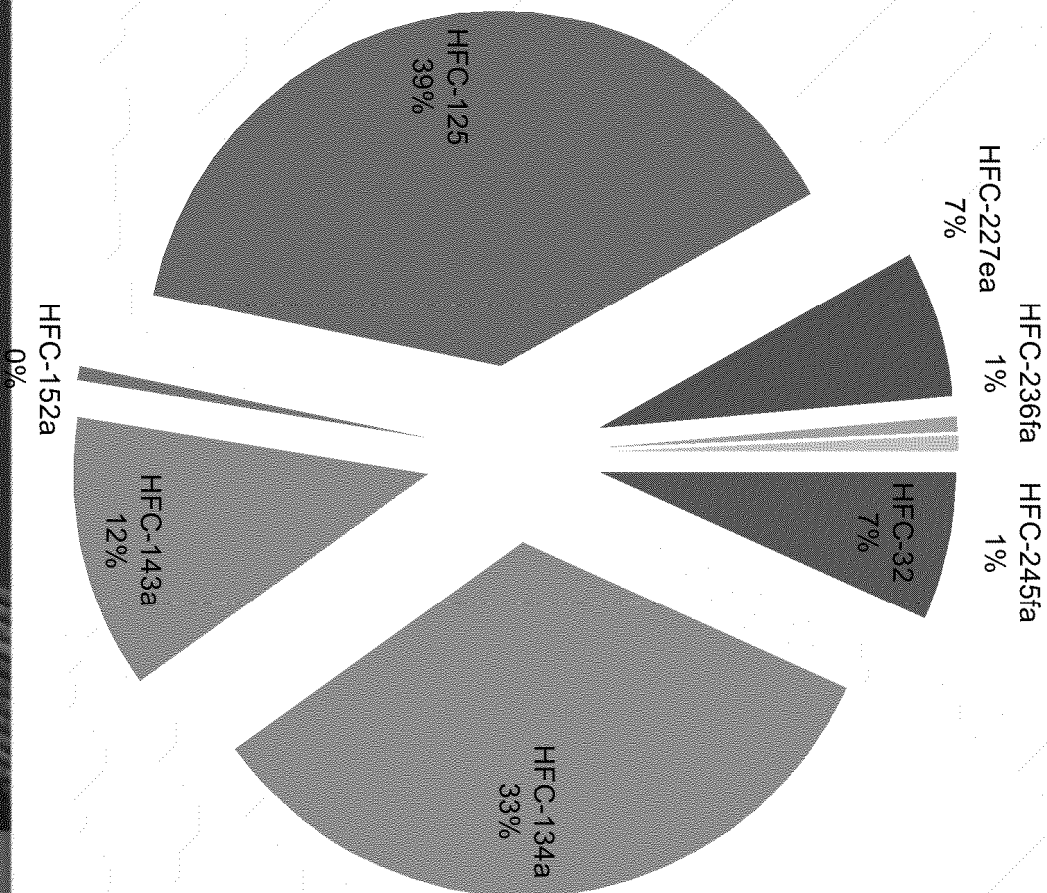
Sales distribution (by metric tons in 2009)



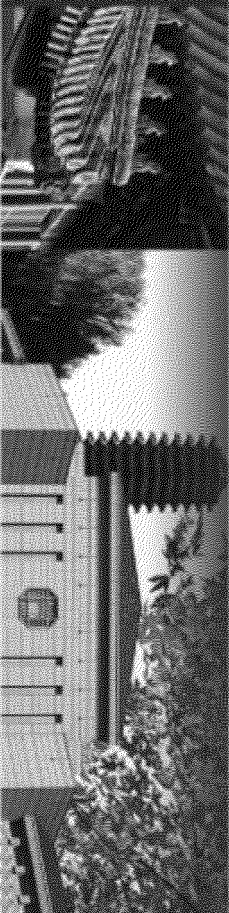
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Sales distribution (by GWP)



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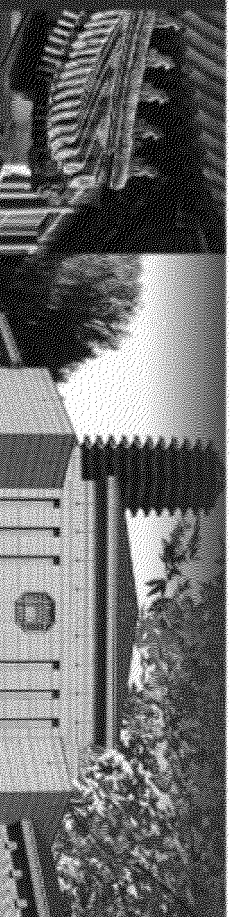


Factor of product export

- Consumption does not mean emission in China
 - Such as HFC-410A consumption by room air condition (~35% export)
 - China export 1/3 of the RAC, HFC-410A for US, EU, Japan and other developed countries
- In fact, HFC-134a is the biggest source of HFCs domestic



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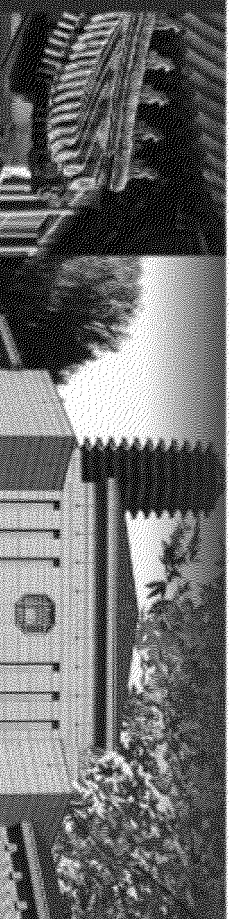


How will HFCs go?

- In 2010, automobile production/sales reached 18 million;
- In 2010, room air-condition production is close to 100 million (the largest consumption sector of HCF-Cs in China)
- They are the two bigger sectors related to HFCs (already)



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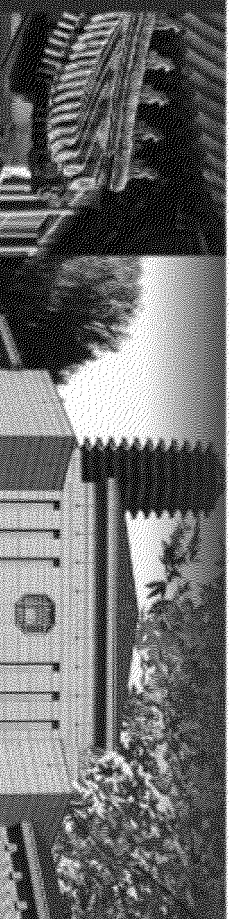


Industry and commercial sector

- > 50,000 tonnes of HCFCs + HFCs in 2010 (~80% of HCFCs)
- Alternatives??



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Case study

HFC-134a

- MAC

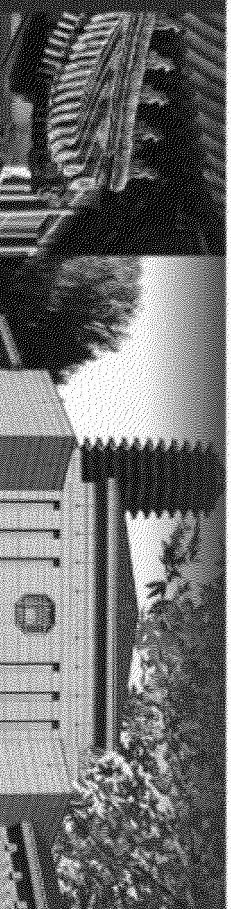
HFC-410A

- RAC

HFC-23



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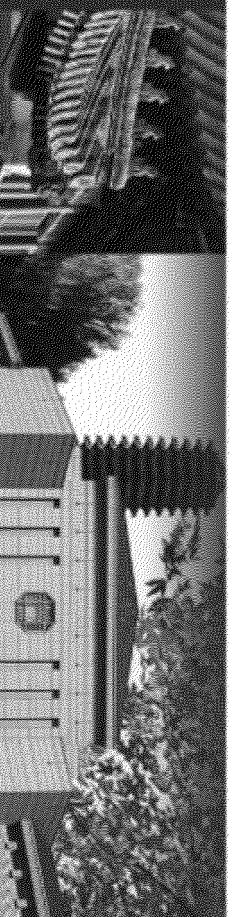


Main works

- the baseline scenario and control scenarios
 - established model based on emissions of HFCs
- Alternative technologies for MAC and RAC
- Conduct scenario analysis to carry out reduction potential of GHGs



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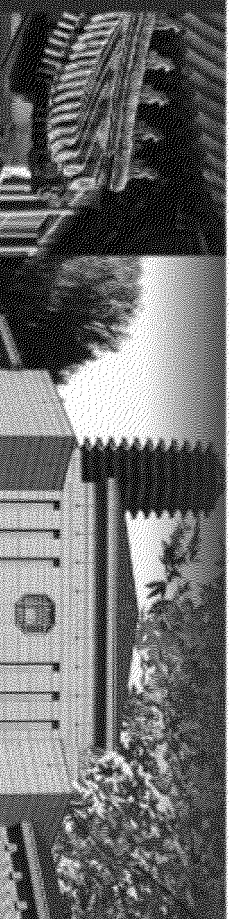


Alternatives for MAC and RAC

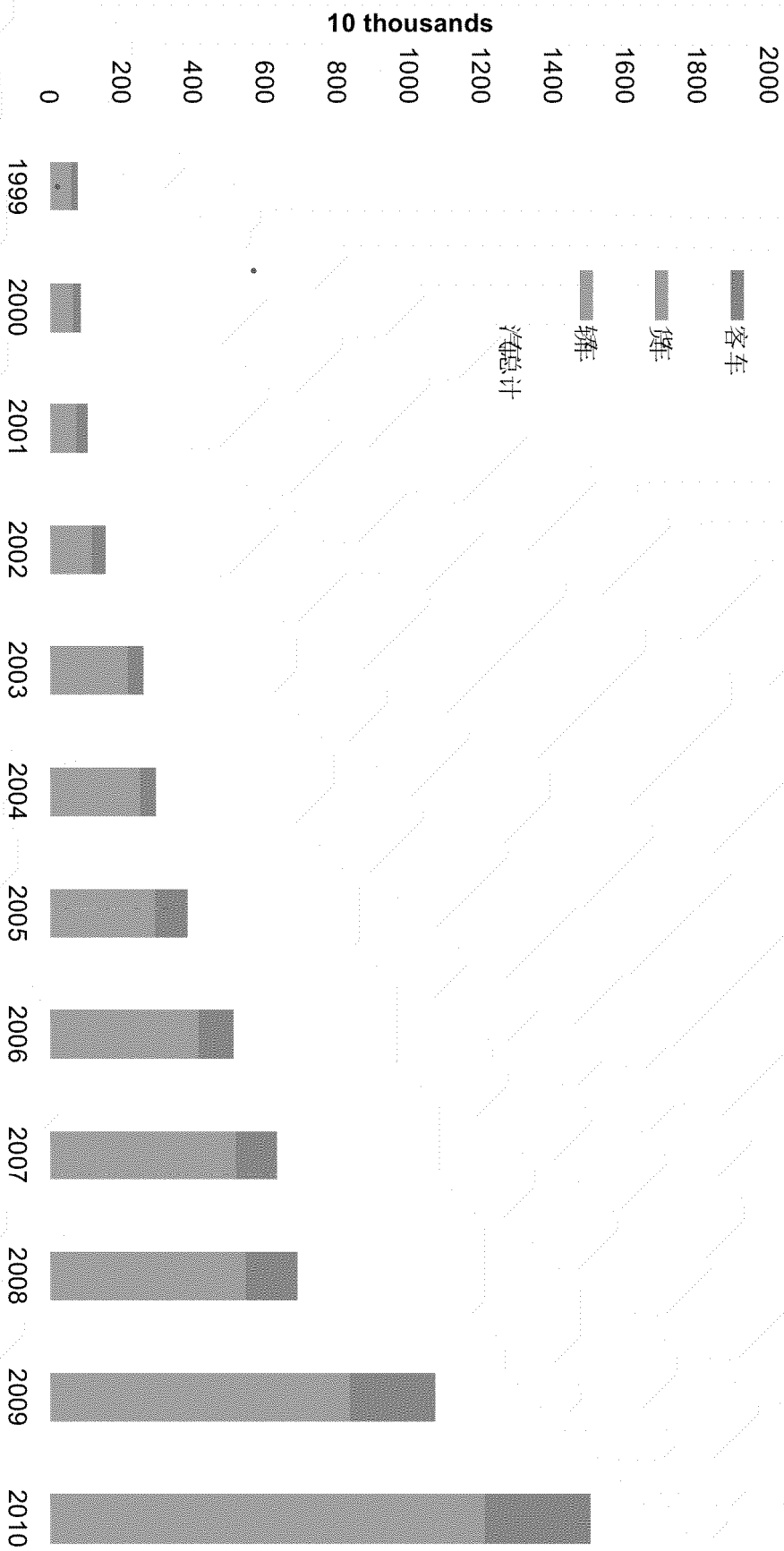
- HFC-134a
 - HFC-152a
 - HFC-1234yf
 - CO₂
- HFC-410A
 - HC-290 (propane)
 - HFC-32 (difluoromethane).



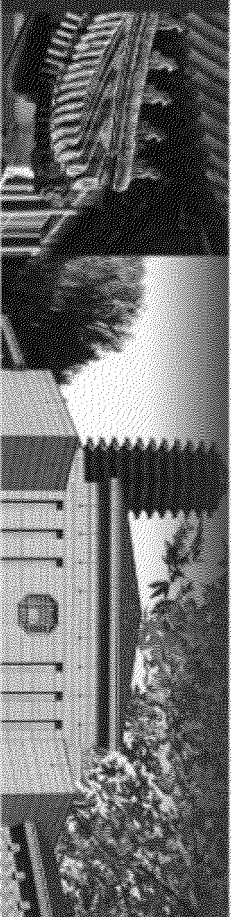
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Production of Total Mobiles and Mobiles with MAC in China



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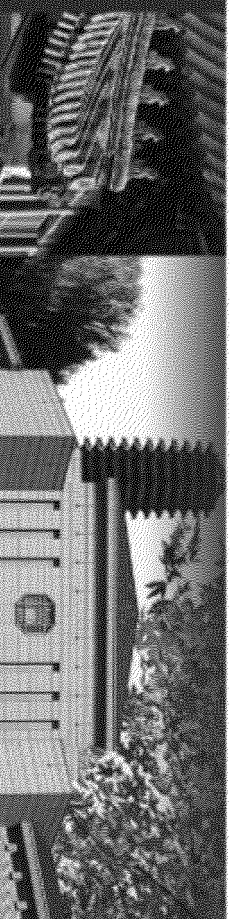


MAC sector

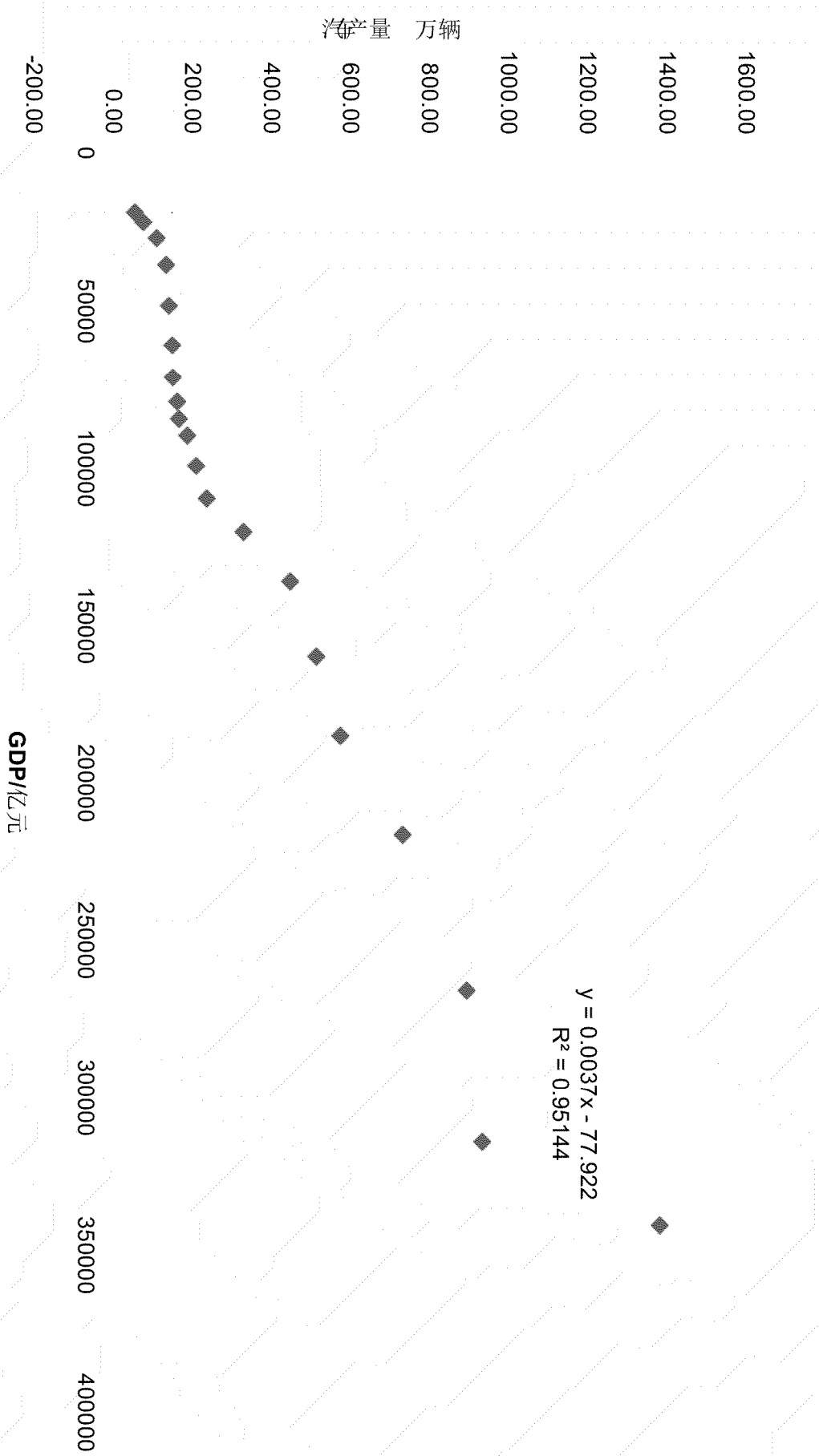
- The study selected three indicators of GDP, population and disposable income of urban residents, and other factors affecting the demand for autos.



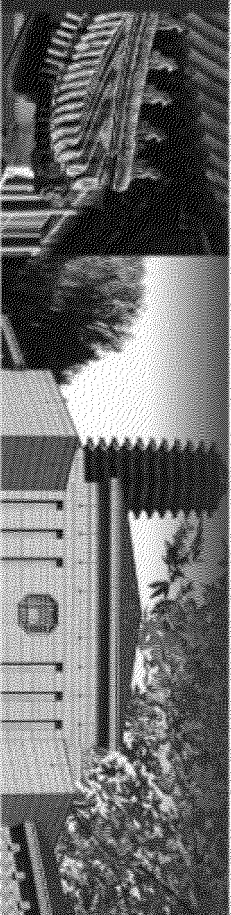
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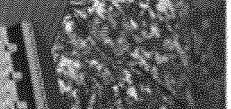


Auto demand and GDP correlation analysis

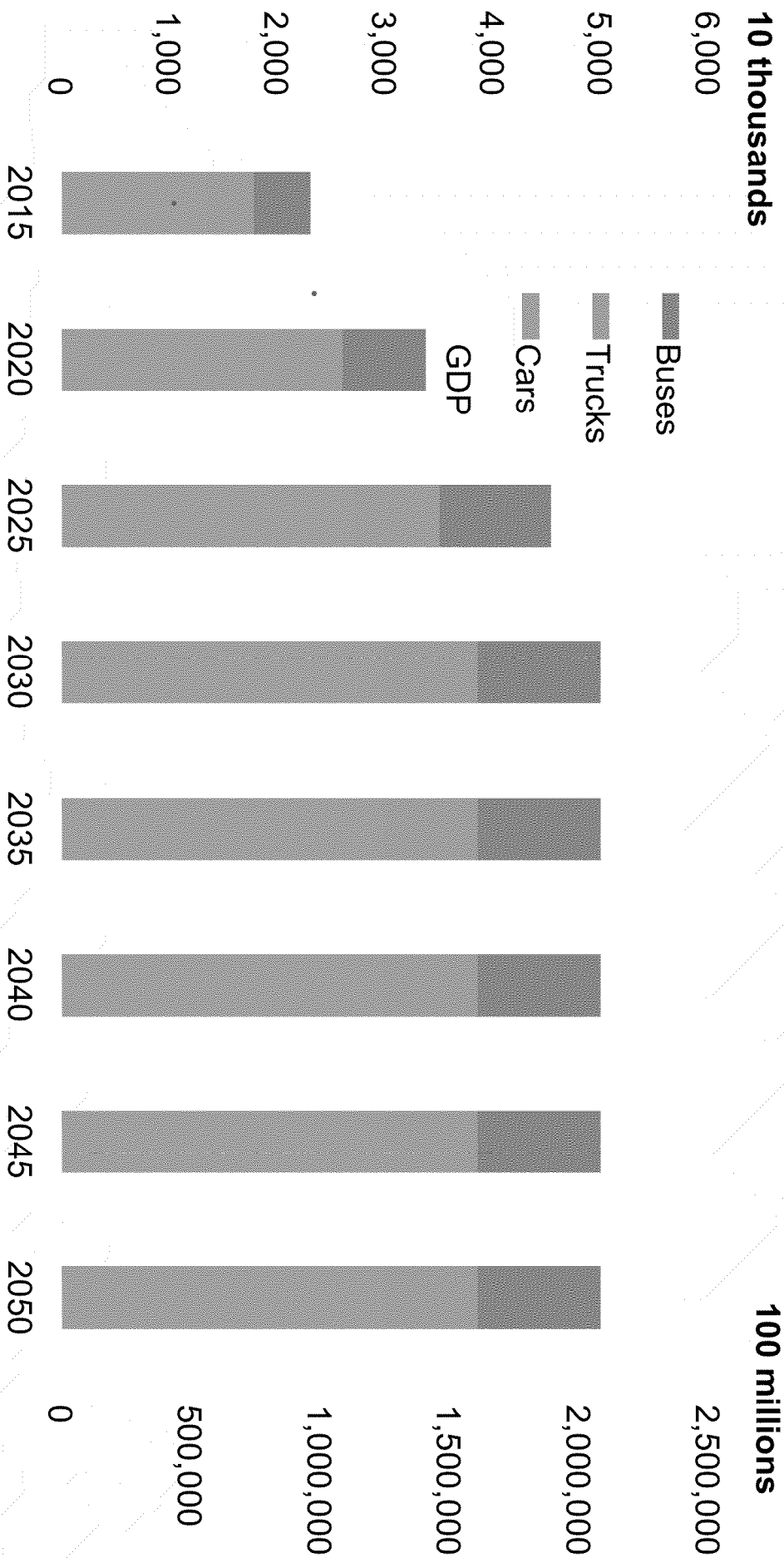


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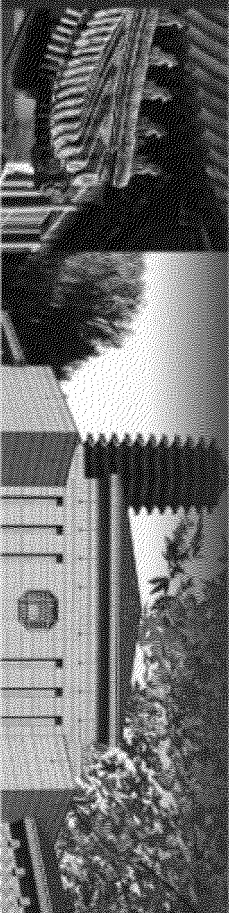




Forecast demands of vehicles in China for 2015-2050

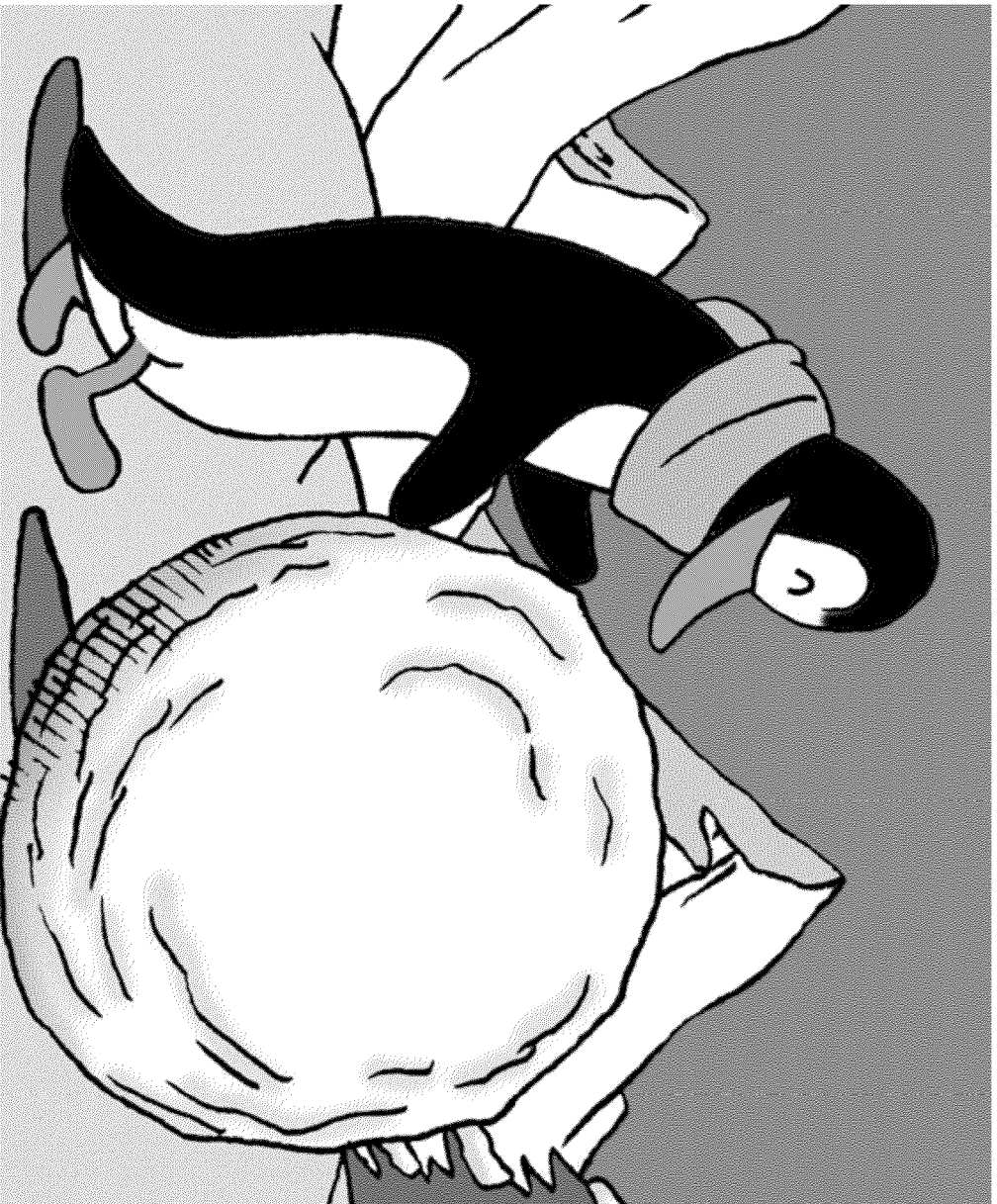


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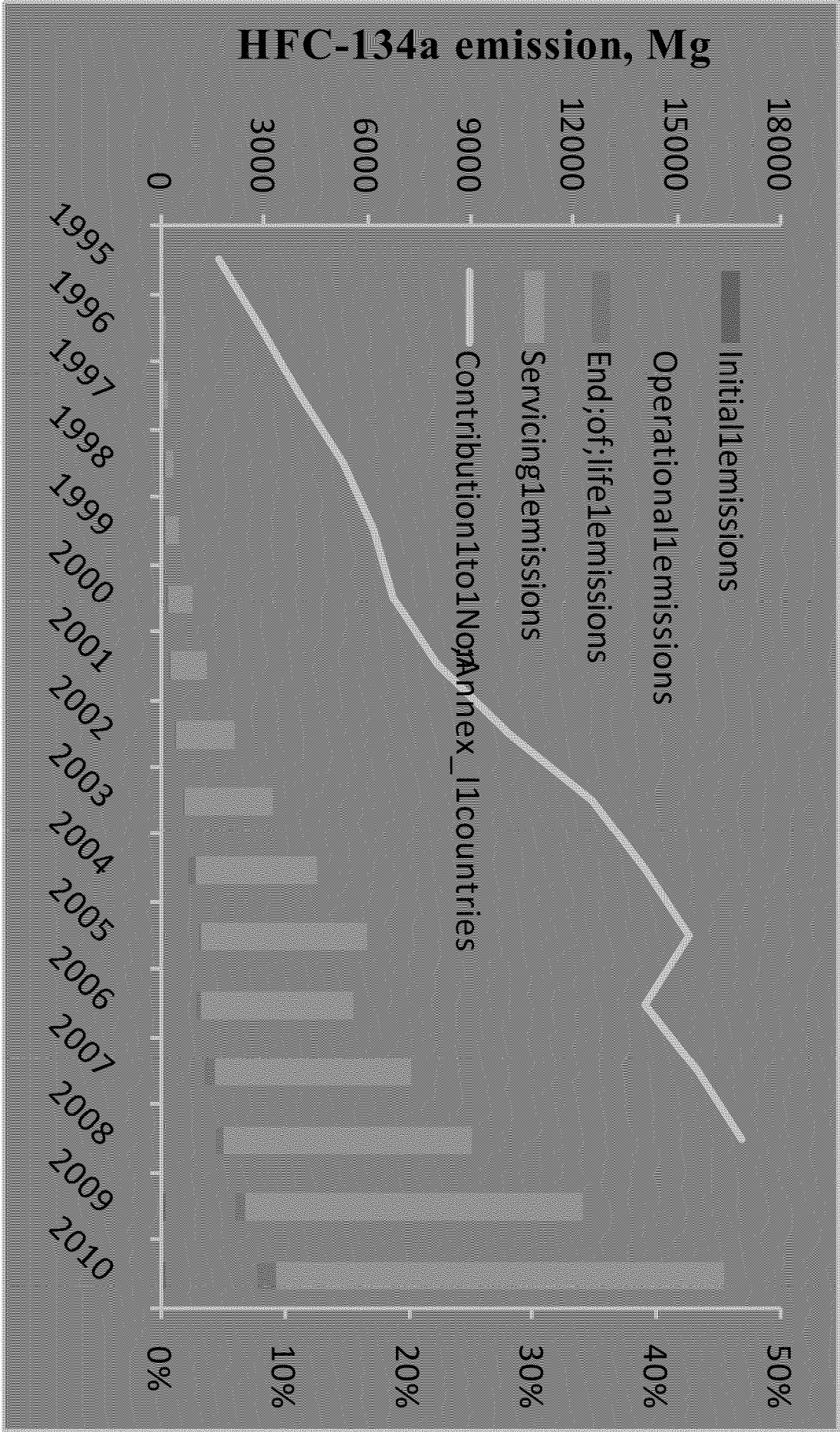


Servicing will play more important role

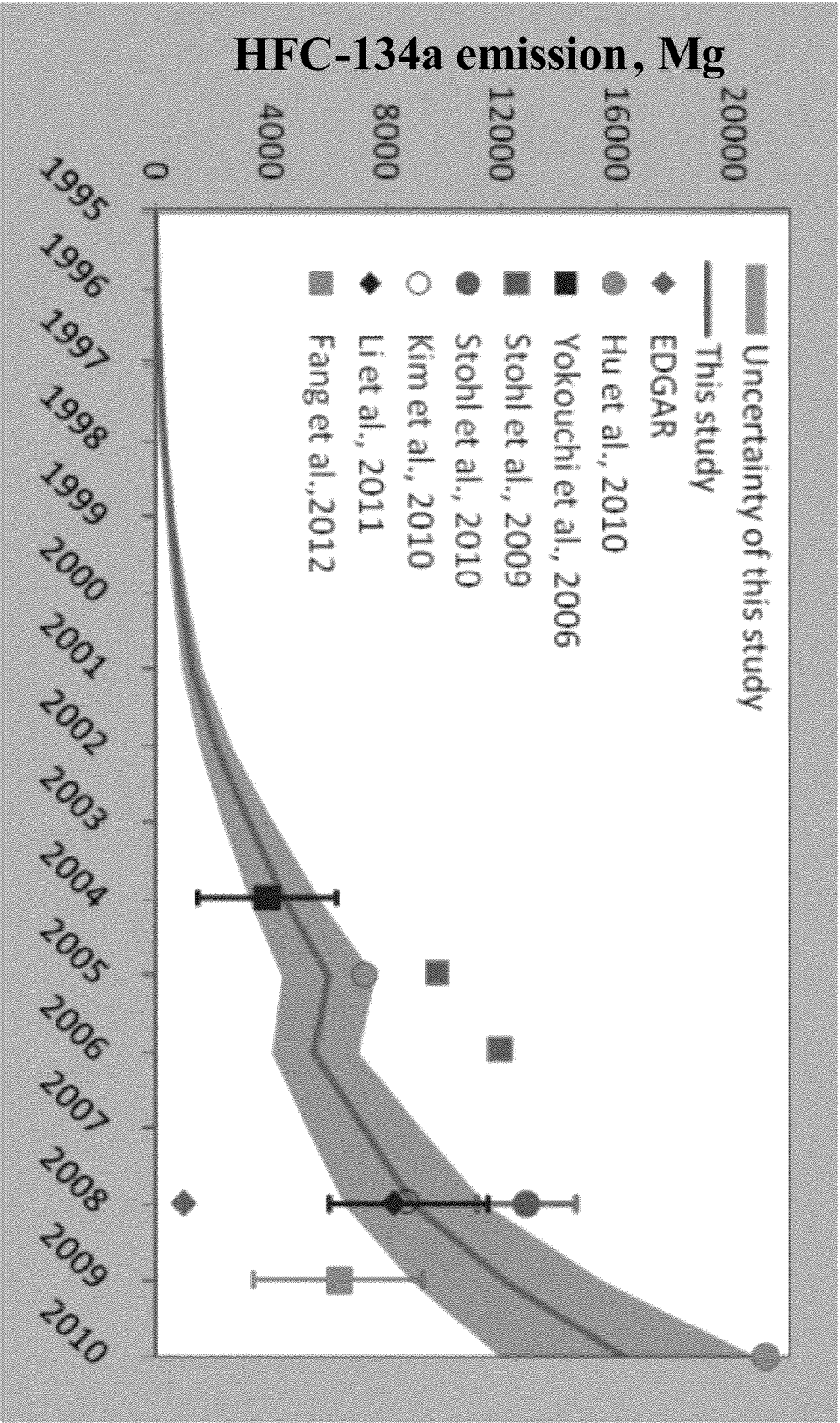
installation of HFC facilities would be increased every year



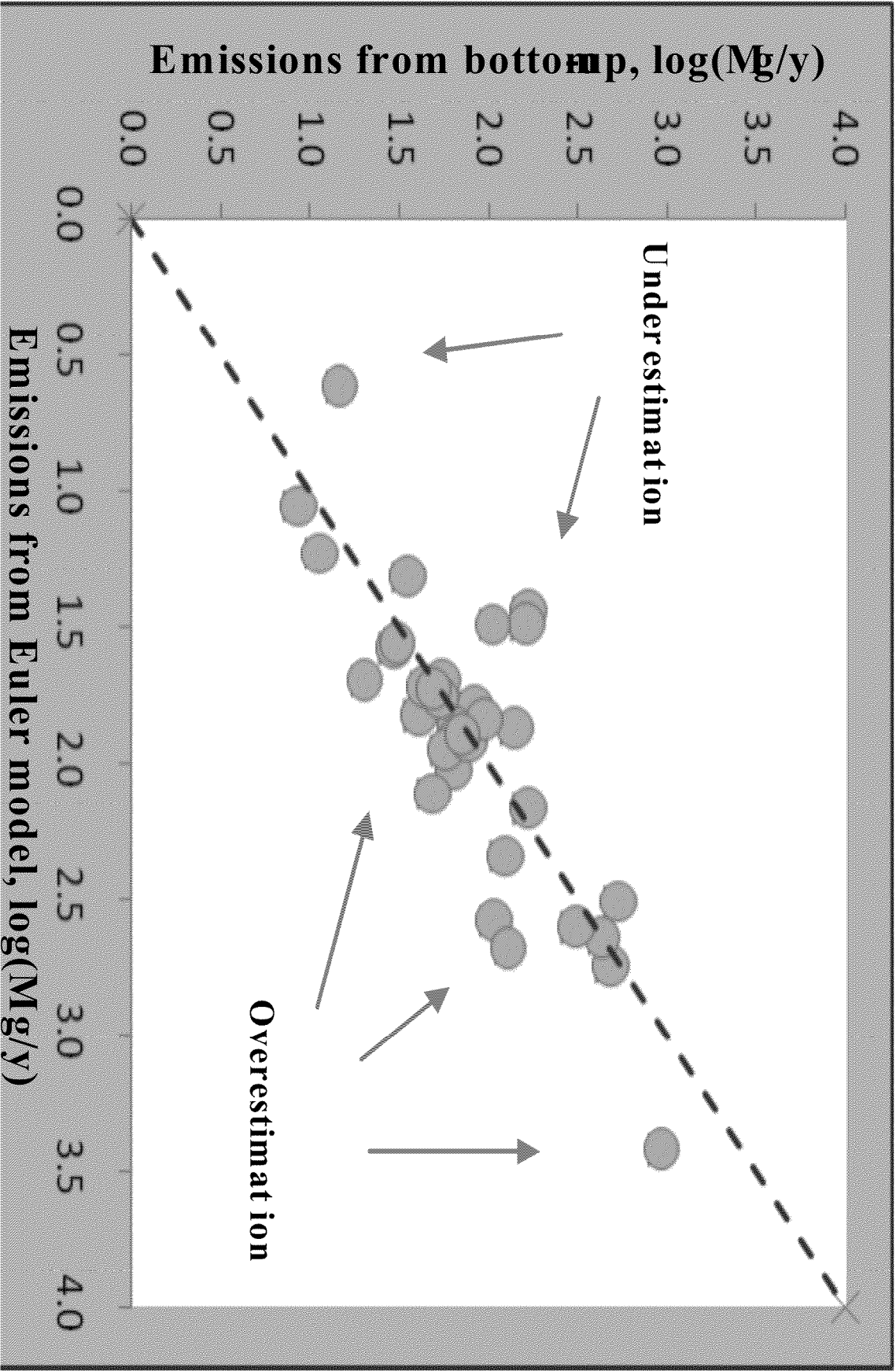
Emissions from MAC sector



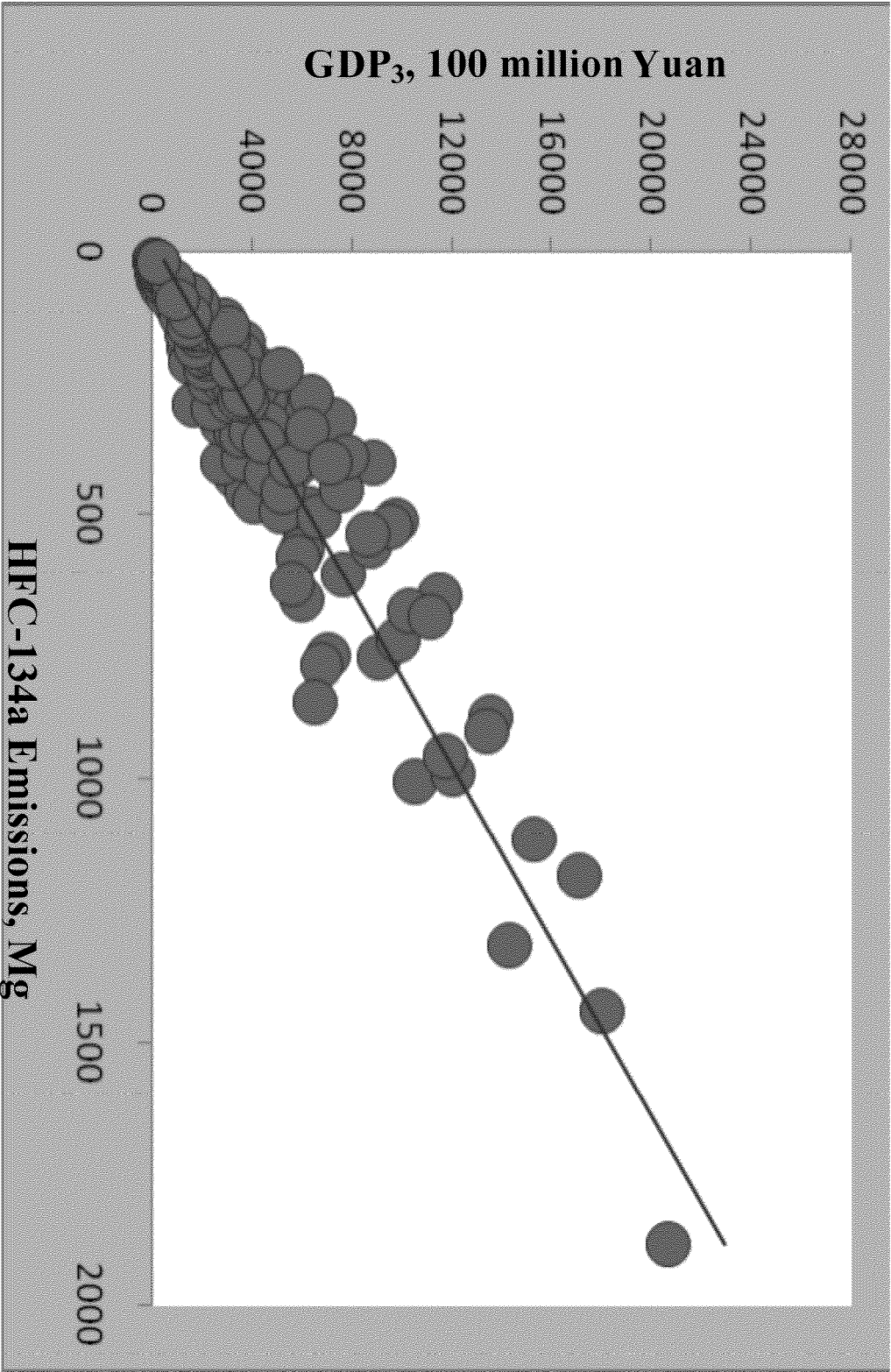
Uncertainty of emissions and comparison with reported estimates



Comparison between emissions of bottom-up method and Euler model



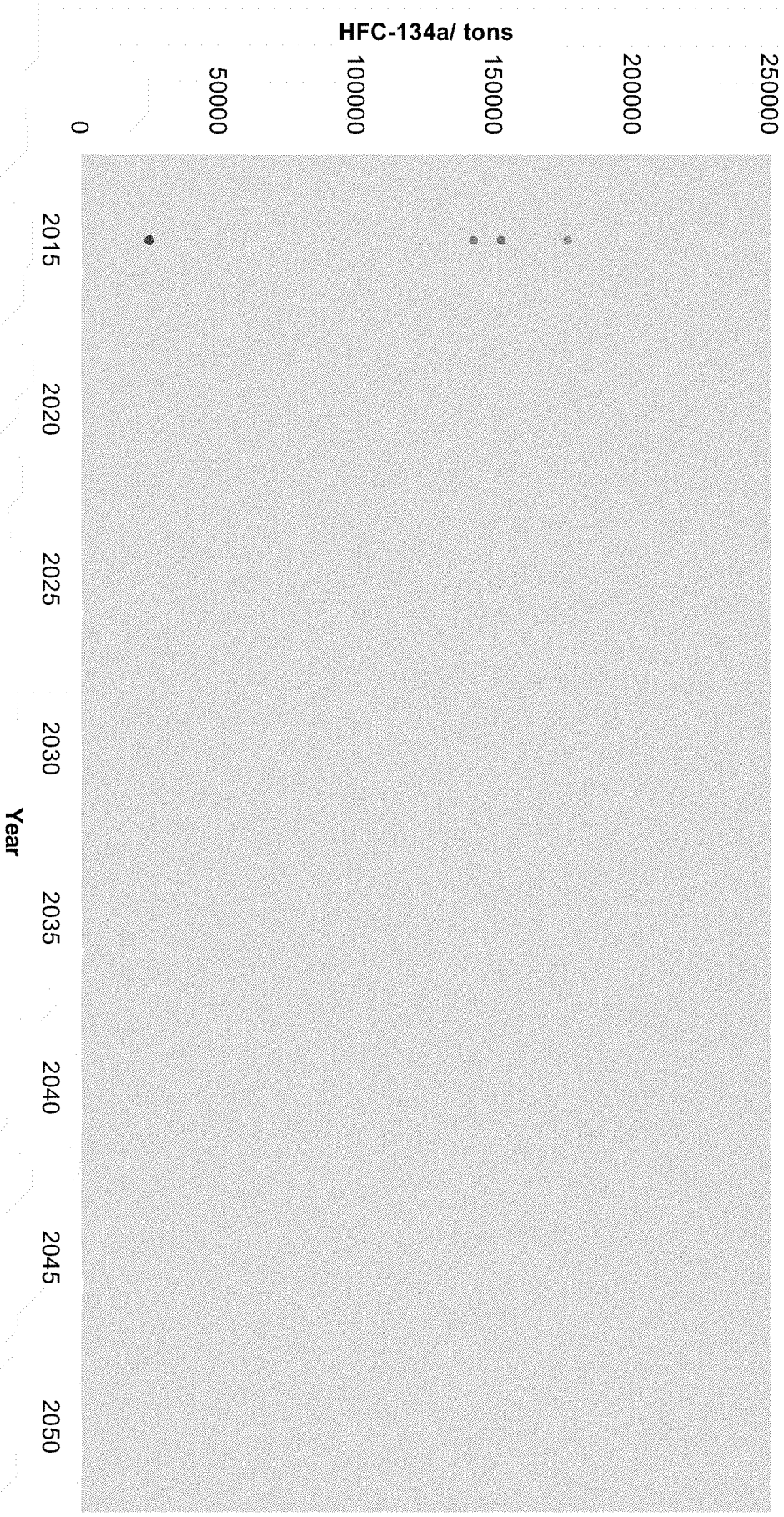
Correlation relationship between provincial emissions and GDP (2006-2010, $p=0.944$)



Design of controlling scenarios

	Control	information source
controlling scenario A (S-A)	Begin in 2016 and finish in 2020, linearly within 2016 -2020	According to the reduction target of China in 2020. HFC -134a is one of controlling gas. It is the most extreme situation.
	Using HFO -1234yf as alternative	Assumption, according to the developed countries.
	Using HFC -152a as alternative	Assumption, partial alternative have similar GWP
controlling scenario B (S-B)	Begin in 2021 and finish in 2030, linearly within 2021 -2030	10 years later than EU F -gas regulation
	Using HFO -1234yf as alternative	Assumption, according to the developed countries.
	Using HFC -152a as s alternative	Assumption, partial alternative have similar GWP
controlling scenario C (S-C)	Begin in 2018 and finish in 2034, linearly within 2018 -2034	MP abatement proposed by the North America countries for developing countries
	Using HFO -1234yf as alternative	Assumption, according to the developed countries.
	Using HFC -152a as alternative	Assumption, partial alternative have similar GWP

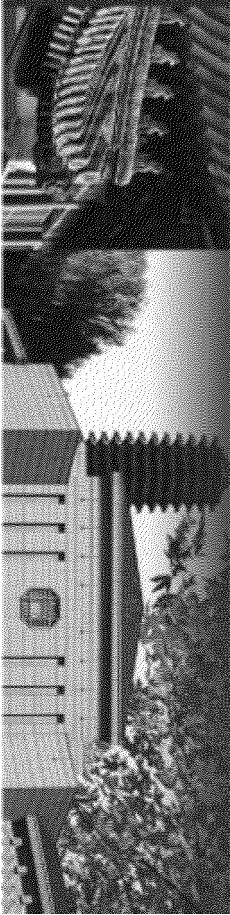
HFC-134a/MAC



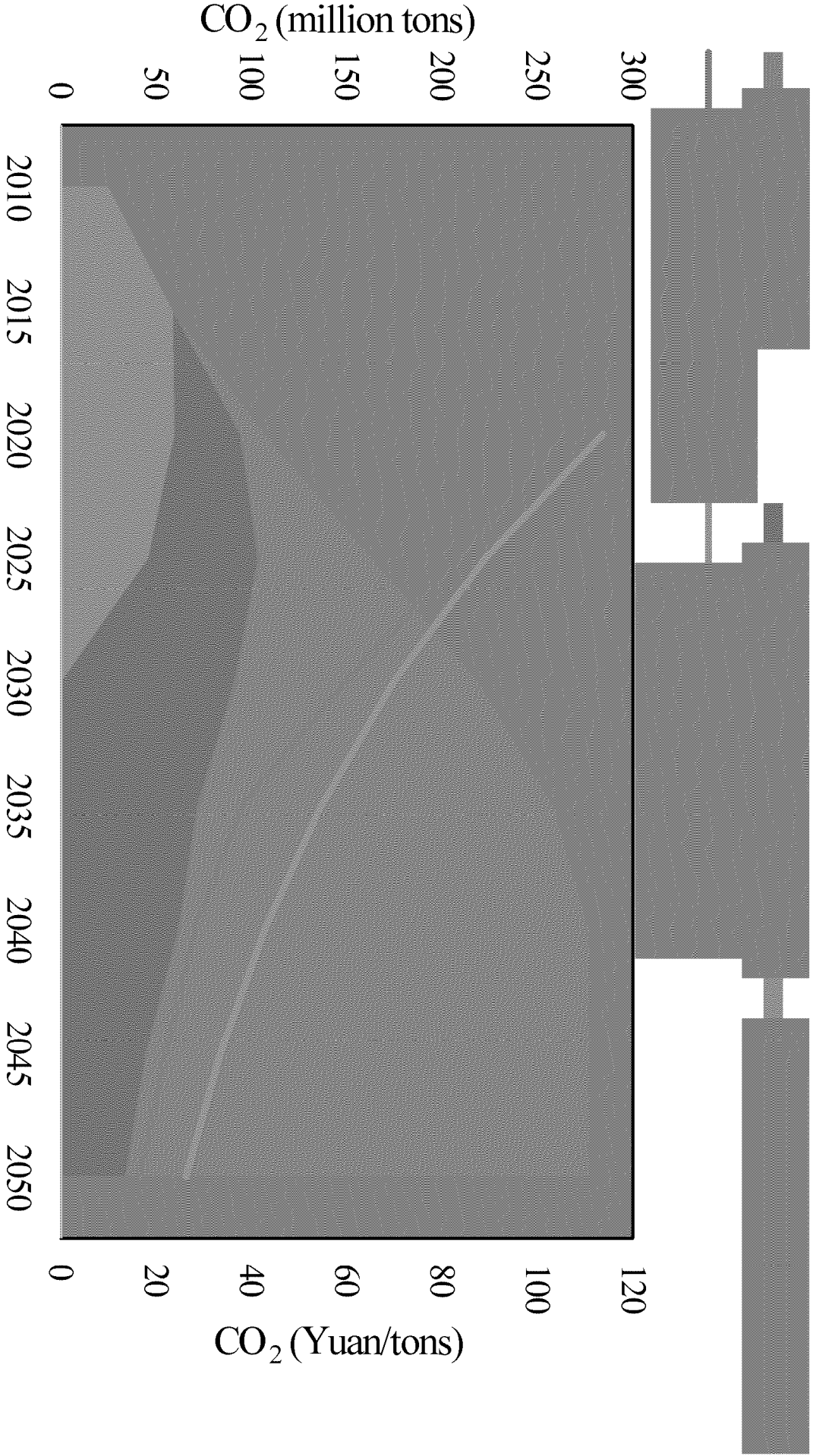
基线情景 情景A 情景B 情景C



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The HFC-134a emission-reduction potential and cost of the MAC sector

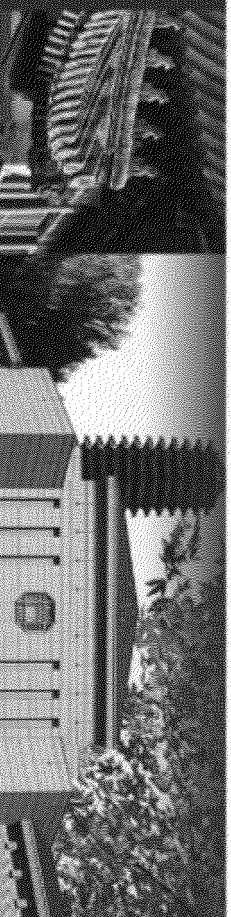


RAC

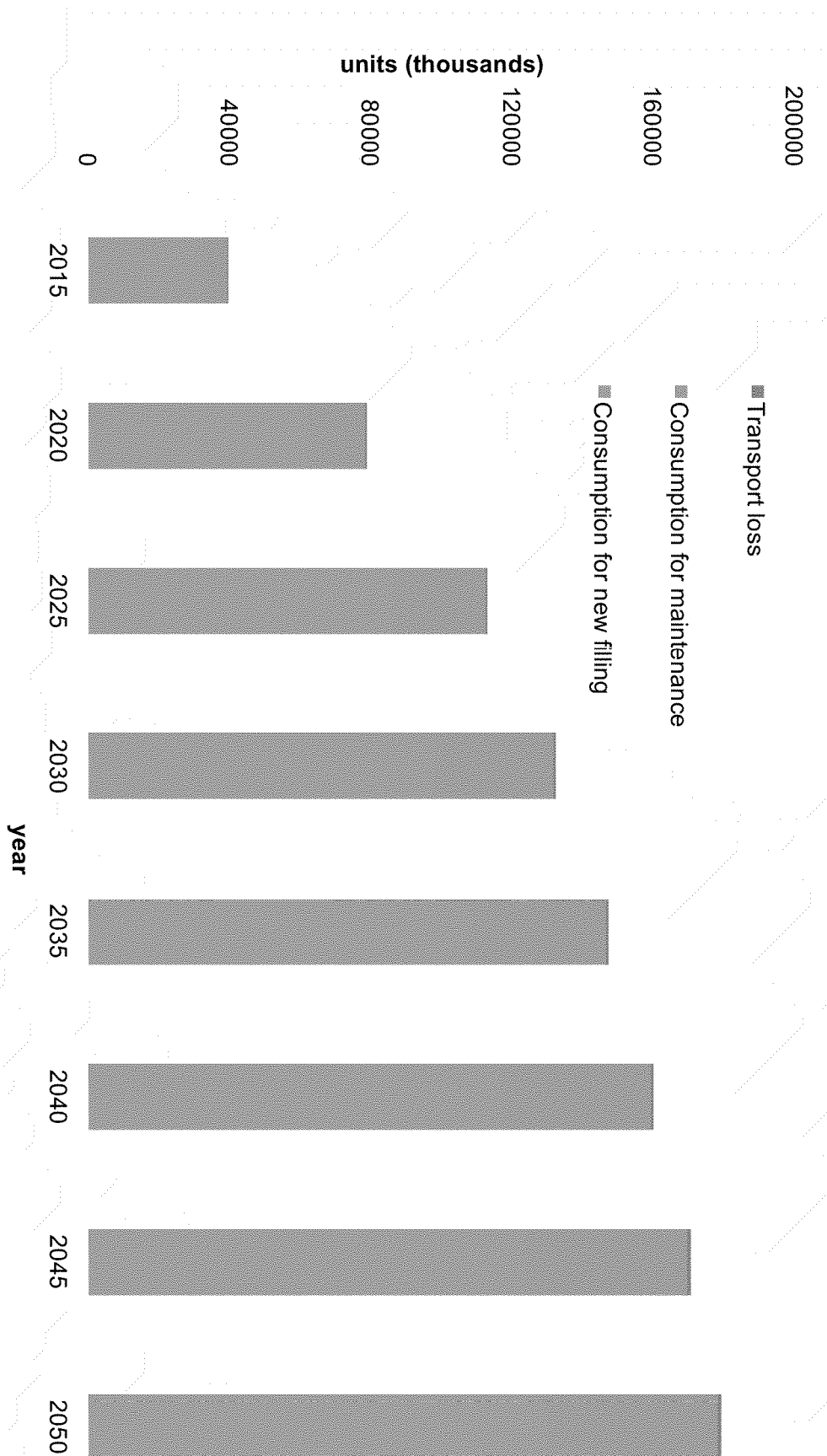
- HFC-410A used for export RAC long time (US, EU, Japan and etc)
- An energy efficiency standards for RAC on June 1 2010 officially implemented.
 - Preliminary estimates, the standard implementation of the annual saving 3.3 billion kwh available
 - HFC-410A used to replace HCFC-22 since 2010



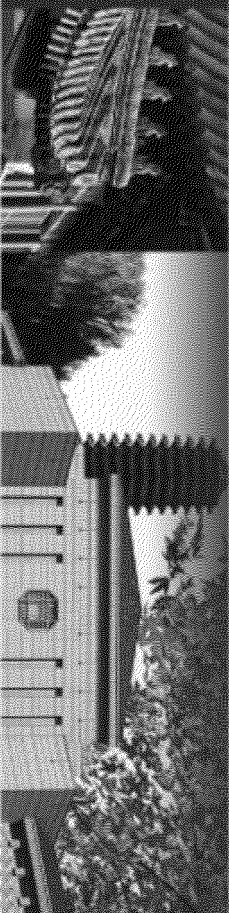
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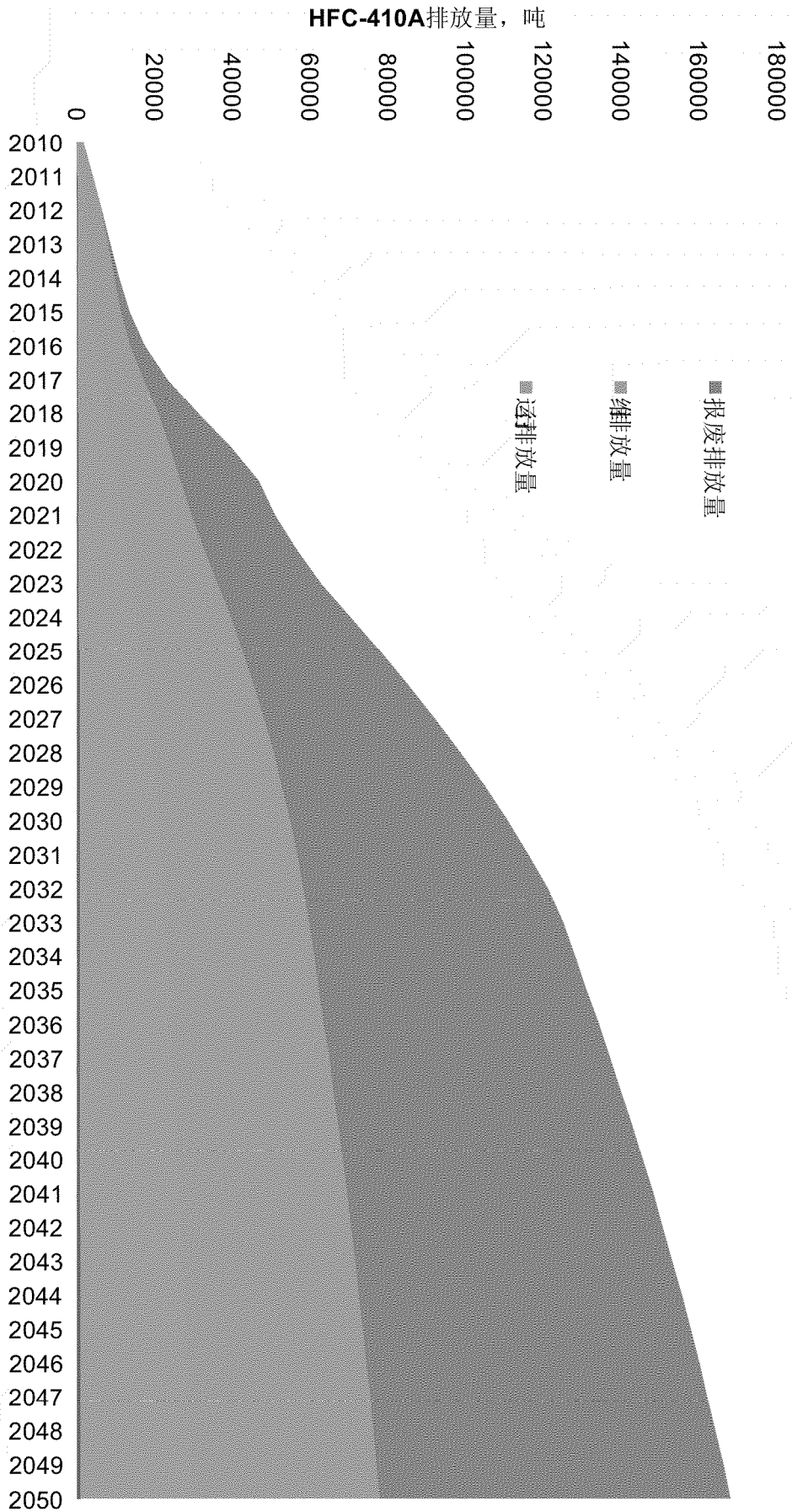
Projected Annual HFC-410A consumptions in RAC sector within 2010-2050



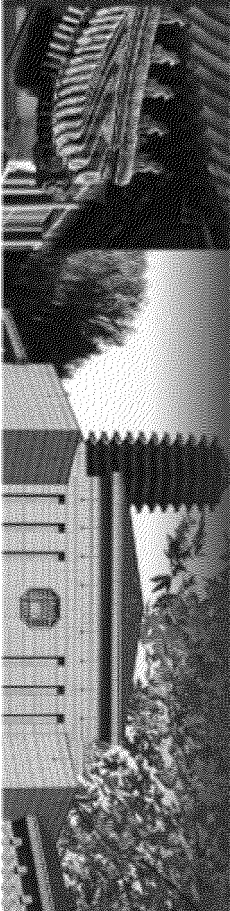
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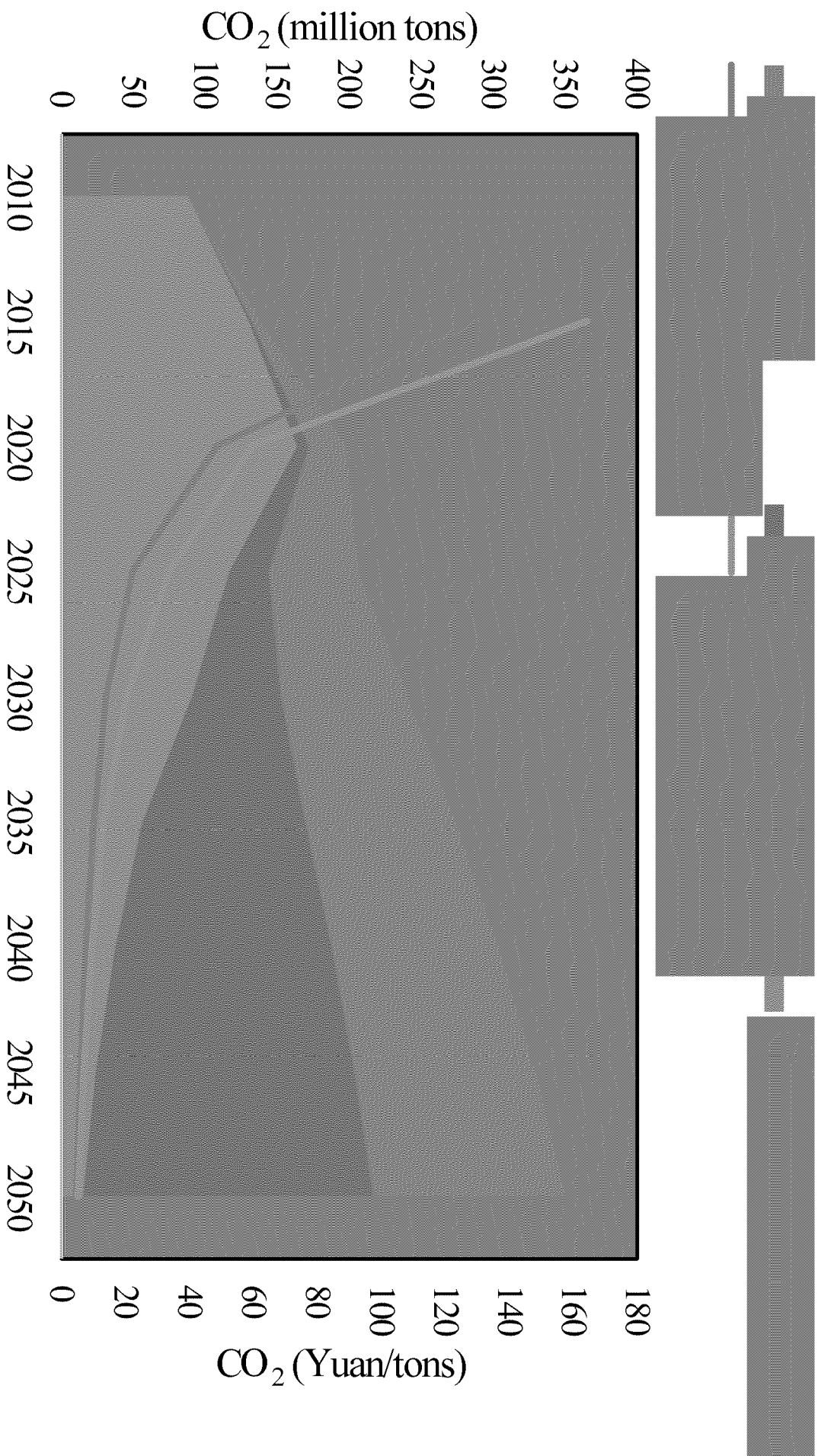
Projected emissions for HFC-410A



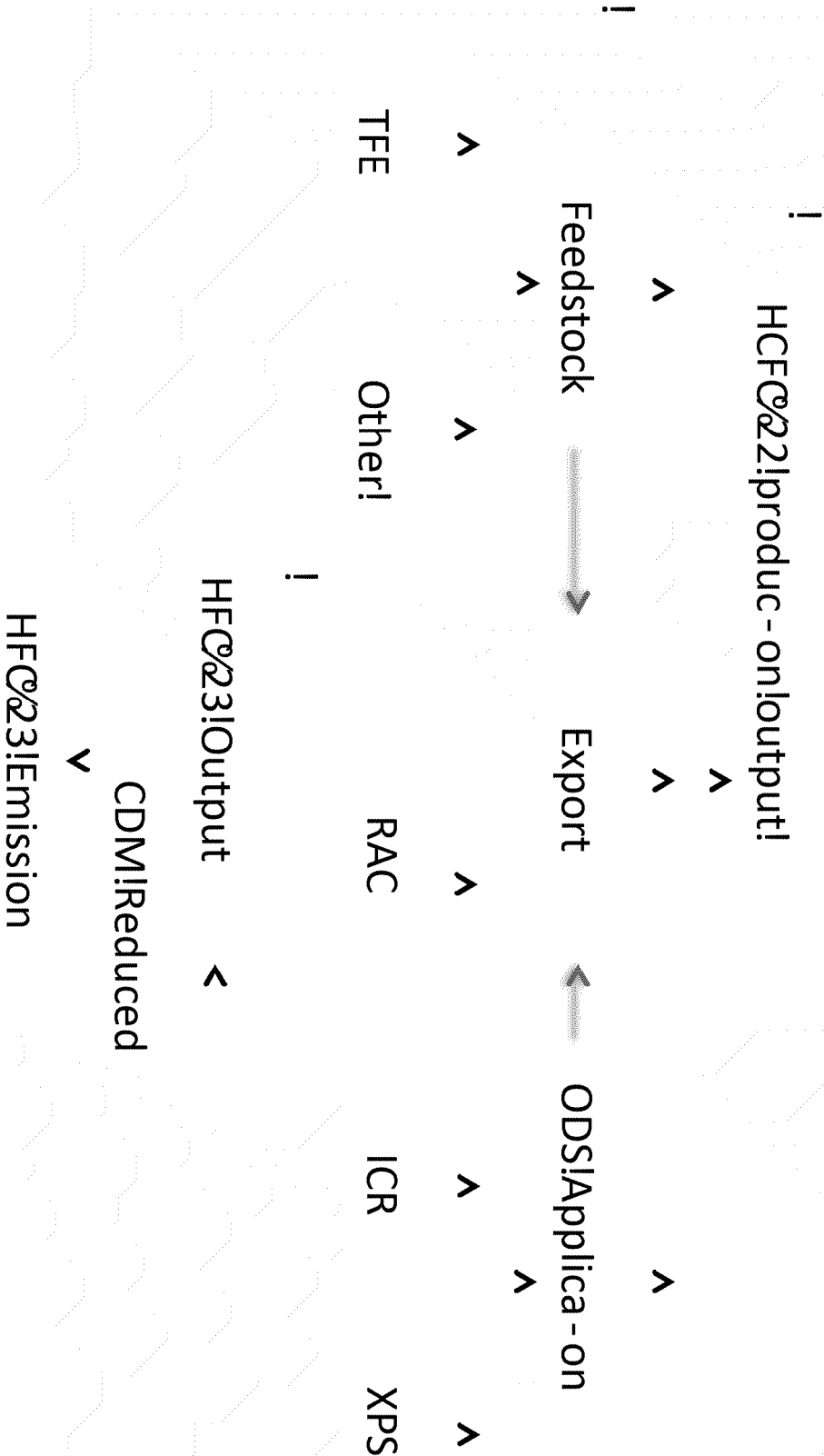
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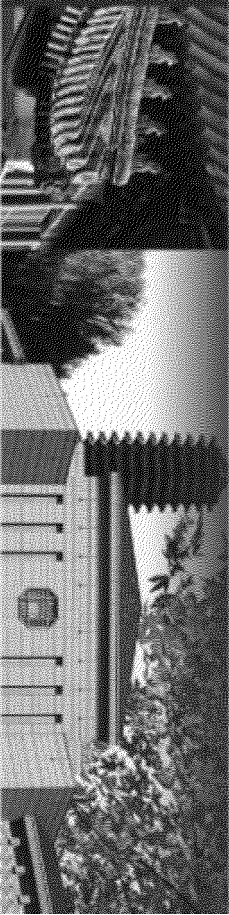
HFC-410A emission-reduction potential and cost of the RAC sector



Technical roadmap to predict production of HFC-22 and emission of HFC-23



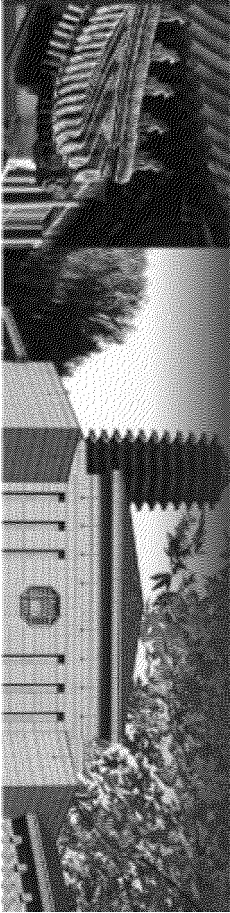
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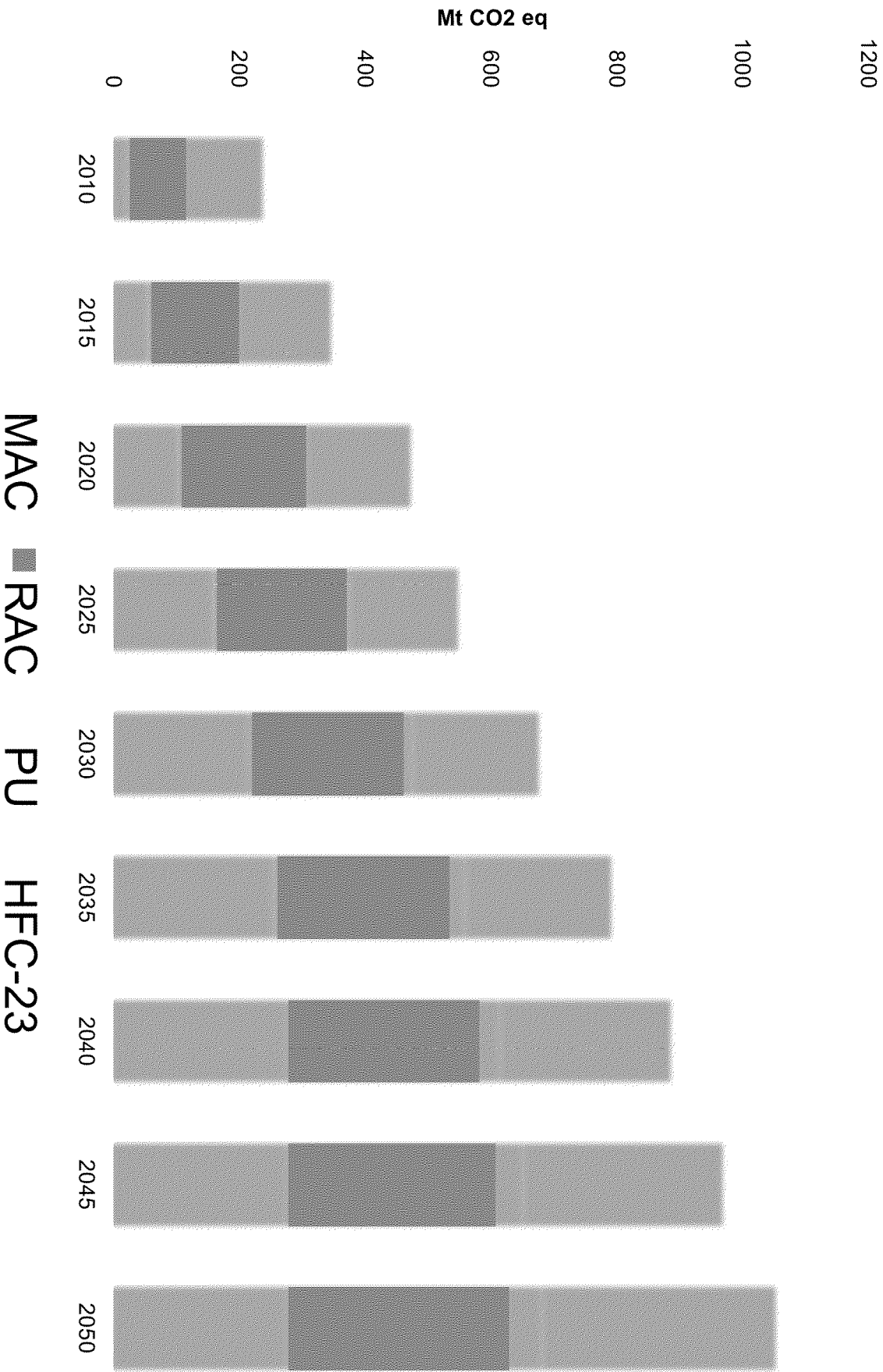
Generation amount and actual emission of HFC-23 in 2000-2010



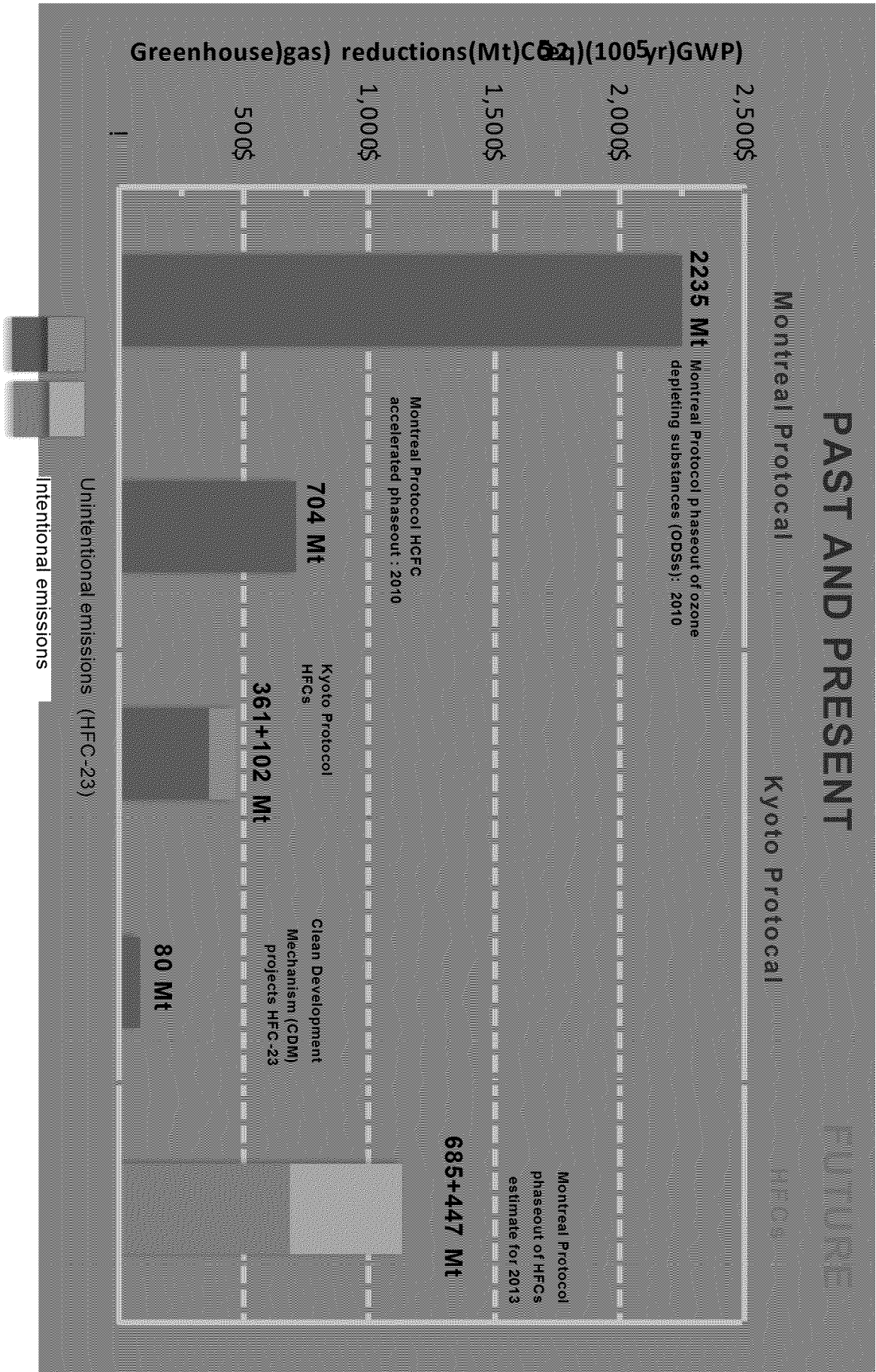
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The predicted emissions under the BAU scenario



Climate Protection of the MP and the KP for China

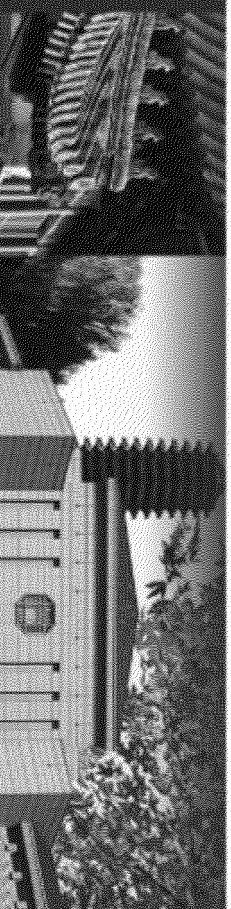


Possible actions on HFCs emission reduction

- Set feasible goals and developing crucial chemical management
- Establish emissions control financial system, promote alternative and emission reduction technology
- Improve laws and regulations related to emission control system
- ReDefine HFCs management organizations and system



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The existing ODS control system is the most suitable institution for managing HFCs

- (1) CFCs, HCFCs and HFCs are products in the fluorine chemical industry
- (2) Consumption application industry for HFCs are basically same with CFCs and HCFCs.
- (3) CFCs, HCFCs and HFCs all are chemicals that caused global environment problems which is environmental protection departments' responsibilities.
- (4) The existing ozone layer material policy management system has gone through more than 20 years of development, establishing the involvement mechanism including department, associations, enterprises, specialists, public and the international society.



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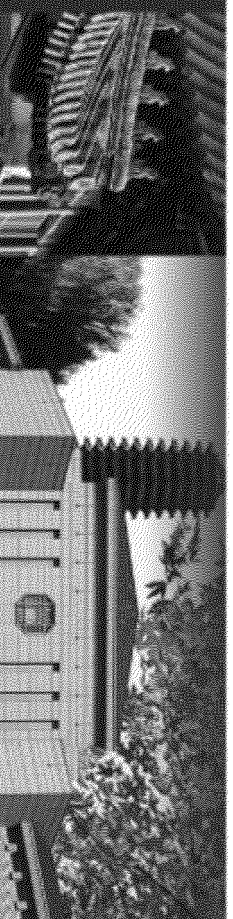


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0 Executive Summary

0.1 Environmental impact and global actions of HFCs

In order to protect the global environment, one of primary tasks is to control Greenhouse Gases (GHG) emissions. The certain fluorinated GHGs (F-gas) emissions are extraordinarily important emissions among all the GHG emissions, because the concentrations of F-gases (mainly HFCs) are increased very fast during last decade. The applications of fluorine-containing gases widely involves many areas, and F-gas plays important roles in the global economy development.

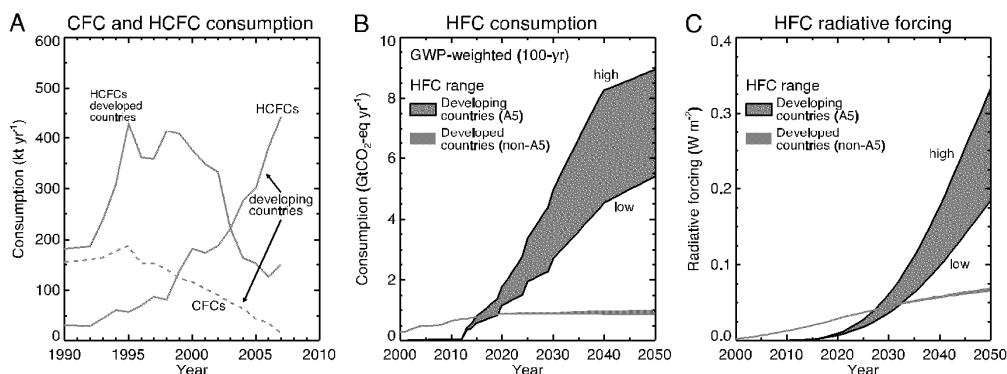


Fig. 1 CFC and HCFC consumption in the past (A); HFC consumption in future (B), and HFC RF (C) for 2000–2050 in developing (A5) and developed (nonA5) countries.¹

During 1750 to 2000, the totally direct radiation force caused by the increase of the industrial produced halocarbon is $0.33 \pm 0.03 \text{ Wm}^{-2}$, which is equivalent to 13% of the total radiation force caused by the increase of all mixed GHG in the same period (IPCC, 2007). And so far, the proportion of HFCs is not high among all the fluorinated GHGs (CFCs, HCFCs and HFCs, etc.). Based on “the Montreal Protocol on Substances that Deplete the Ozone Layer” (short for the Montreal Protocol or MP), the developed countries will phase out hydrochlorofluoro carbons (HCFCs) by 2020. Developing countries will start to phase out HCFCs from 2013 and phase out 97.5%

¹ The large contribution of projected HFC emissions to future climate forcing, PNAS July 7, 2009 □ vol. 106 □ no. 27 10949–10954

of HCFCs by 2030 . HFCs as one of the main alternatives would be introduced for replacing HCFCs. Prediction by Velders shows, based on situation forecast of the current policy technology and relevant international conventions invariable , the consumption of HFCs will up to 5 -9 billion tons CO₂eq in 2050 (Velders, 2009), and the totally radiation force is 0.18 -0.33w/m². And based on the Kyoto Protocol (hereafter KP), the targets of emission reduction is about 2 billion tons per year during 2008-2012 year (Velders, 2007). The growth of HFC emissions is higher enough to offset the benefit achieved by Kyoto protocol for implementation of GHG emission reduction.

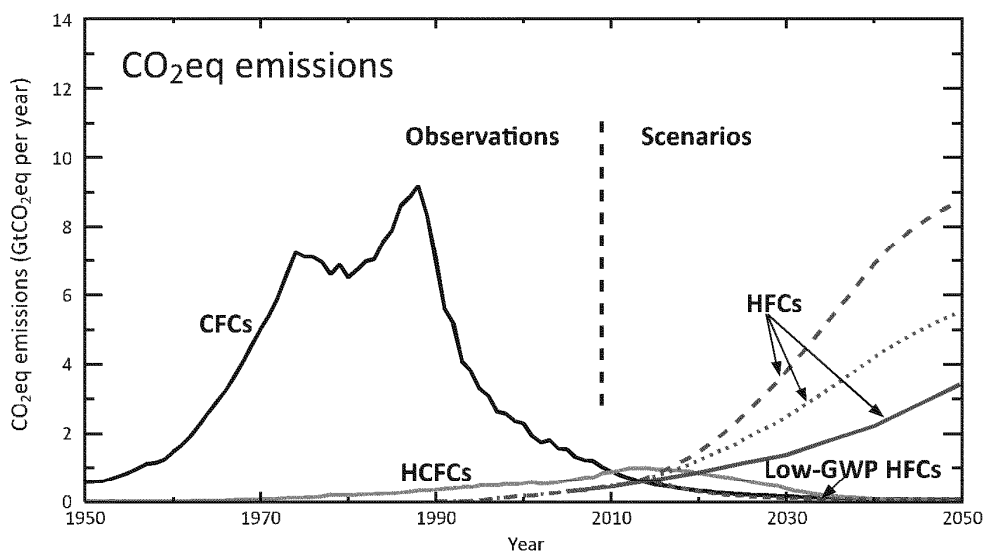


Fig. 2 Trends in CO₂eq emissions of CFCs, HCFCs, and HFCs since 1950 and projected to 2050²

On the other hand, the emission reduction of HFCs are happening, the emission reduction potential of HFCs in developing countries are high.

In order to protect global environmental, HCFCs and HFCs will be the current and future core of fluorinated GHG control in China and global. HFCs are the main alternatives of HCFCs and CFCs. Then the consumption and emission of HFCs would grow rapidly, while phasing out the HCFCs. After years of development, the total emission load and discharge structure of GHG has changed a lot in China and other countries. Effecting by industrialization and export growth, fluorine -containing GHG

² HFCs, a Critical Link in Protecting Climate and the Ozone Layer, UNEP, 2011

grow rapidly on production, consumption and emissions , and arouse wide concern in the international community.

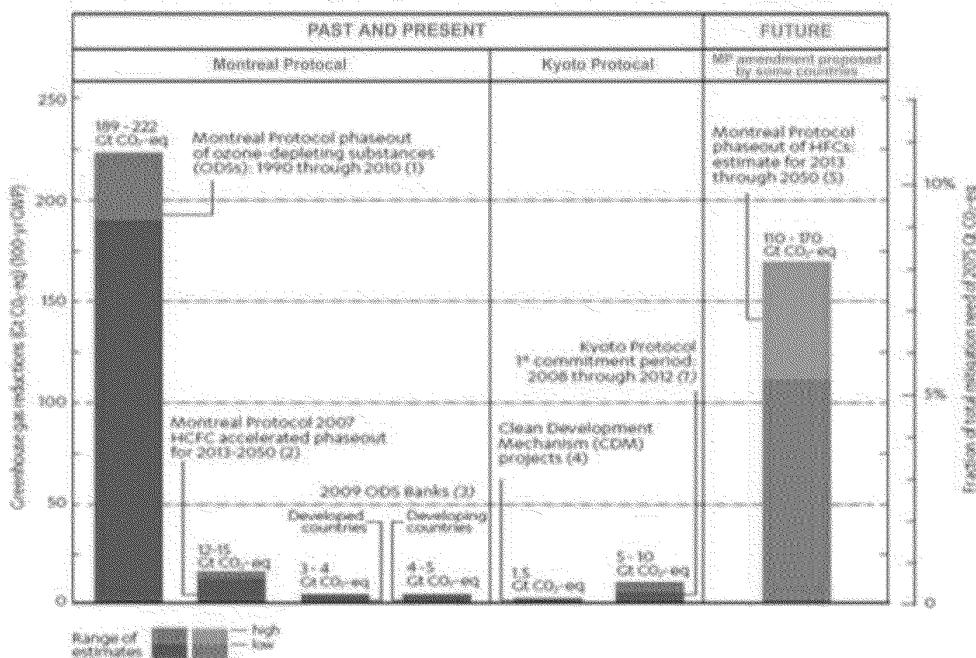


Fig. 3 Climate Protection of the Montreal Protocol and the Kyoto Protocol

In order to control the growth rate of HFCs consumption and emission , the United States, Canada and other countries put forward to speed up the elimination of HFCs, and mean to add HFCs control terms into the Montreal Protocol (amendment) since 2009. In February 2012, the U S A, Canada and other countries established " the Climate and Clean Air Coalition (CCAC)" that also supported by UNEP , and focused on three kinds (classes) of GHG including HFCs (other for methane and black charcoal). All countries in G8 have become the member of the alliance.

0.1.1 Applications Hydrofluorocarbons (HFCs)

Based on the Montreal Protocol , CFCs, HCFCs and all Ozone depleting substance (ODS) should be phased out. HFCs are one of the main alternatives of them, therefore the consumption of HFCs are grown rapidly driven also by the ODS phaseout, except the emission of HCFC-23 which is the by-product of HCFC-22.

Table 1 Main applications of HFCs

Substance	HFC-134a	HFC-125&HFC-32	HFC-245fa	HFC-152a	HFC-227ea
application fields	Automotive air conditioning refrigerant	Residential air conditioner refrigerant	foaming agent	Refrigerant in refrigeration equipment	fire extinguishing agent
	Refrigerant in refrigeration equipment	Refrigerant in refrigeration equipment	Solvent	foaming agent	
	Medical aerosol				
	others		others		

0.1.2 International countermeasures

The developed countries have begun to control HFCs. In June 2000, the European Union has started the "action plan for climate change", and the reduction of HFCs in all fields is proposed. The European Union countries have adopted various means to control and cut down the emissions of HFCs. Such as increasing GHG tax, limiting the usage and formulate specific cuts solution in Britain and France, to reduce and control the production and consumption of HFCs and PFCs.

On December 7, 2009, the USEPA pass two orders on the Clean Air Act indicative terms, which are about GHG in the environment and the health effects (202a): One is "the increased concentration of the current and future expected six main GHGs, carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O), hydrogen fluoride carbon (HFCs), perfluorocarbon (PFCs) and sulfur fluoride (SF₆), will threaten the health and welfare of contemporary and future generations". The second is "the new motor vehicle and new motor vehicle engine is an emission source of the GHG, which threat the public health and welfare". This will be the basis for provides the legal and administrative management to the USA to control HFCs GHGs. On June 5, 2010, The USA, Canada and Mexico propose to amend the Montreal Protocol to include HFCs in Montreal Protocol.

The Chinese government signed the Kyoto Protocol (KP) in 1998, and the KP formally went into effect in 2002. As a developing country, the Chinese government is not liable for carbon dioxide emissions reduction obligations temporarily. However,

the international society pays a lot attention to the green gas discharged by China. Especially in 2009, the Chinese government lay out specific targets for cutting 40-45% GHG emissions per GDP by 2020. Control and phase down HFCs become an important topic.

0.1.3 The opportunities and challenges of HFCs control management in China

Controlling emission of HFCs became one of the cores of global concern. Since Feb. 2012, the CCAC were established by USA, Canada and other countries, besides G8 countries, many developing countries have become the member of the alliance. And the considerations about the specific emission reduction goals, the cost of emissions reduction, and how/who should cut down HFCs emissions. Meanwhile, the climate effects caused by GHG emissions are still the most basic scientific issues. Nowadays, China's consumption and production of HFCs has already taken a substantial proportion in the whole world. Meanwhile it is another tremendous pressure for China that has to phase out HCFCs at the same time, if more HFCs are selected as alternatives for HCFCs phaseout. The international society pays a lot attention to the actions of HFCs control taken by China.

The concentration growth rates of HFCs in atmosphere are higher than any other GHG since 2005. The study also shows that the concentrations of HFCs are increase rapidly in China too. The environment concentration of HFCs changes rapidly, which confirm the need of emission control for the environmental protection requirements.

Based on the Montreal Protocol, Chinese government will start to phaseout HCFCs from 2013. And the consumption and emissions of HFCs will grow rapidly. Chinese government means to avoid using HFCs as the alternative of HCFCs; however the other alternative technologies are hard to be obtained, unsafe and/or low efficacy. HFCs are one of the main alternatives of HCFCs, even the only alternatives in some industries (sectors) that increasing the difficulties of HFCs control in China.

0.2 HFCs status and their alternatives

0.2.1 HFCs production and consumption in China

Various HFCs are produced and consumed in China recently, including HFC-134a (mobile air-conditioner, industrial and commercial refrigerant, medical aerosol), HFC-410A (residential air-conditioner, industrial and commercial refrigerant combined with HFC-125 and HFC-32), HFC-245fa (blowing agent), HFC-152a (blowing agent and refrigerant), HFC-227ea (fire extinguishing agent), HFC-143a (industrial and commercial refrigerant) and so on. Based on information from the web³, from the year of 2010 to 2011, production of HFC-134a had increased from 63000 tons to 84000 tons, and production of HFC-125 had increased from 40000 tons to 59000 tons, and production of HFC-32 had increased from 42000 tons to 50000 tons, what's more, HFC-152a production in 2011 approached 5000 tons. If accounted by CO₂eq assuming all produced emitted, then the total produced HFCs in China are 361 million tons of CO₂eq in 2011.

Besides the domestic consumption in China, in fact the HFCs are exported in two ways, firstly, exported directly as chemical, that included HFC-134a especially; secondly, exported with manufacture equipment, such as HFC-410A charged in residential air conditions.

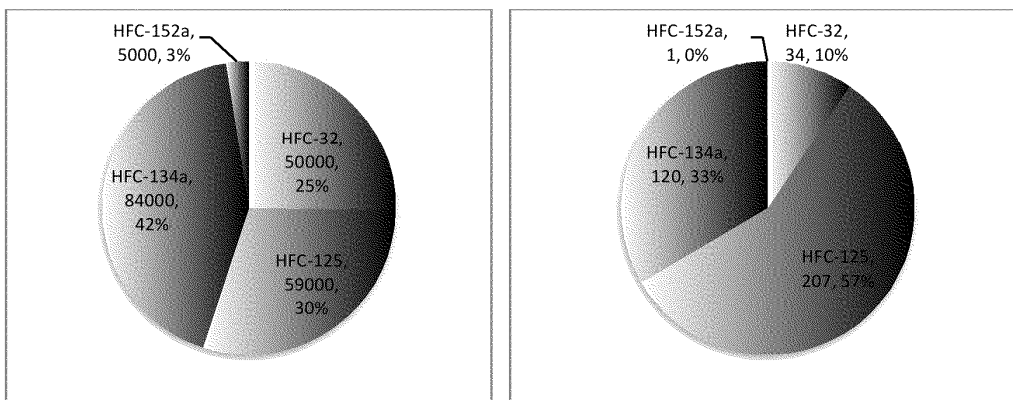


Fig. 4 The Production of main HFCs in China in 2011 (in tons) (A); The Production of main HFCs in China in 2011 (in million tons of CO₂eq) (B)

³ <http://www.chinaiol.com/>

0.2.2 Technical options for alternatives

In faced of various kinds of alternatives with advantages and weakness for each one, careful assessments and choosing is quite necessary, which offers China crucial reference for future HFCs control and management.

The main principle should be followed in the process of assessment include:

Starting from alternatives' basic physical and chemical properties, we should select the crucial factor and analyze properties related to application in different sectors, concerning alternatives' flammability and toxicity. As to replacement of blowing agent, thermal conductivity is the major influential factor, and when it comes to alternatives to refrigerant, energy efficiency ratio, boiling point and vapor pressure, temperature glide as well as HC's explosion limit should be taken into consideration.

As to feasibility, restriction and range of application, we should analyze the application status and future limits for alternatives developed by China, offering reference for developing cheap and feasible alternatives.

We should also define major sector and recommend suitable replacement for crucial sectors and replacement. Application prospect of natural product should be paid attention although there are still some obstacles at the present stage, such as HC is highly explosive and flammable and its performance is worse which cause the terminal products (say, fridge, freezer, air conditioning equipment) consuming more electricity.

Alternatives developed by China's have been applied but not commercialized which call for more attention. Additional, replacements' cost and availability are also worth noticing.

Recently, alternatives can be divided into natural chemical, synthesized chemical and mixture. Natural chemical refrigerant, including HC (propane-R290, butane-R600 and isobutene-R600a), CO₂ (R744) and ammonia (R717) are wide spreading nowadays not only in domestic refrigerator field, but also in commercial refrigeration and mobile air-conditioner.

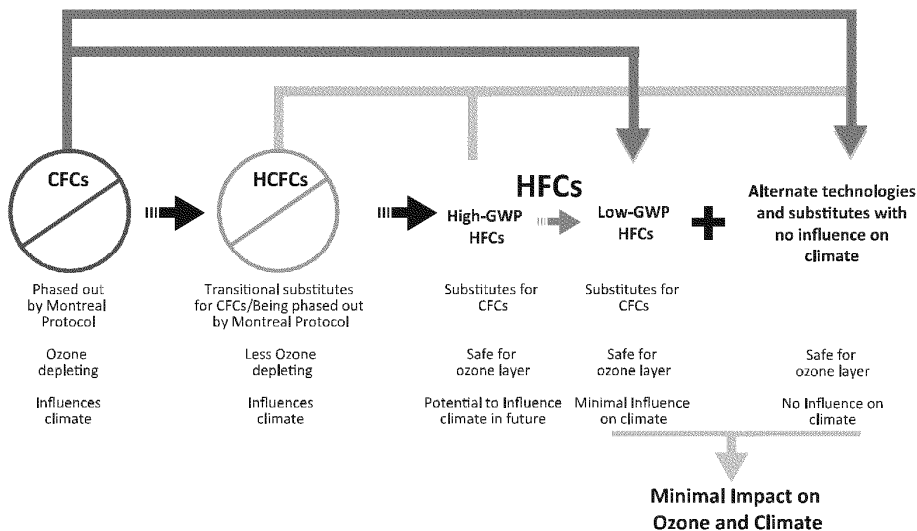


Fig. 5 Flow diagram of ODS Phaseout Process ⁴

In the aspect of synthesized chemical alternatives, HFO's application prospect is the most promising. In 2010 Japan ratified import and application of HFO's refrigerant from Honeywell. And the US EPA approved the refrigerant application of HFO-1234yf in January 2011 as alternative for HFC-134a, which accelerate its commercializing progress.

HFC-134a is widely used as mobile air-conditioner refrigerant. However, due to its high GWP, HFC-134a's global warming effects focused plenty of attention. What's more, the CF₃ group in HFC-134a molecule tends to react with OH radical and ozone, forming TFA which is detrimental to the ecosystem. HFO-1234yf and HFO-1234ze are recognized as suitable current alternative for HFC-134a as new mobile air-conditioner. Honeywell had done plenty of flammability test and risk assessment, leading to the conclusion that HFO-1234yf can be used safely in mobile air-conditioner. Based on the available information, there are no incompatibility issues for HFO-1234yf with plastic and rubber material. Since HFO-1234yf's characteristics are quite similar with HFC-134a, it can be used to replace HFC-134a directly, therefore HFO-1234yf widely accepted by mobile producers. Besides, companies like Delphi and General Motors are developing mobile air-conditioner system with HFC-152a, which does not change the component and production line in current system using HFC-134a as refrigerant in this system with higher performance

⁴ HFCs, a Critical Link in Protecting Climate and the Ozone Layer, UNEP, 2011

coefficient. At present, new researches focus on CO₂ refrigerating system, with the following unique advantages. (1) friendly and safely environment. (2) Thermal physical property can easily adapt current refrigeration cycle and equipment, high refrigerating capacity for unit volume refrigerant and low kinematic viscosity. (3) Qualified flow and thermal conducting property which is helpful in reducing size of compressor. (4) The compression ratio of CO₂ refrigerating cycle is lower than regular system which guarantees the compressor keeping high volume efficiency. CO₂ trans critical cycle is quite suitable for poor working condition like mobile air-conditioner owing to its high exhaust heat temperature and good thermal performance of gas cooler. Besides, CO₂ system's advantage on heat pump offered solution for the problem that modern mobiles cannot provide enough heat in the car. In December 2004, Shanghai automotive industry corporation, Shanghai SanDian BeiEr automotive air conditioning co., LTD. and Shanghai Jiaotong University accomplished the "CO₂ automotive air conditioning compressor and system" program together, which was the first CO₂ automotive air conditioning system prototype in China. However, there is still a long way to go before it's widely applied to the market.

The most common residential air-conditioner refrigerant replacements for HFC-410A are HC-290 (propane) and HFC-32 (difluoromethane). Propane's standard boiling point, critical temperature and pressure are quite similar with the most prevalent refrigerant HCFC-22. Besides, many thermal properties of propane are close to or better than HCFC-22. Another advantage for propane refrigerant is its intermiscibility with mineral oil. Even though its volume refrigerating capacity and refrigeration coefficient is slightly weaker than HCFC-22, its condensing pressure, pressure ratio refrigerating capacity and exhaust temperature are much better than HCFC-22. Under matched condition, its refrigerating capacity can reach 97.2% of HCFC-22 type, with energy efficiency ratio increased by 12.6%. In the domestic air-conditioner aspect, propane's system performance is much better than HFC-410A, therefore as with safety consciousness increasing and relevant regulations, propane has a prosperous prospect in air-conditioner sector.

PU and XPS foam sectors use fluorinated GHGs as blowing agent. Currently, there are 3 alternative techniques in China, (1) HC techniques, including pentane,

isopentane, cyclopentane and some other mixture, the current foaming technique is mature and thermal insulation property is fine. (2) Entire water blowing technique. Water can react with polyisocyanates forming CO₂ and leaving it in the foaming as blowing agent, which can be used as non-insulation foaming, such as high density structure foam plastic (Imitation wood), packing and filling materials. (3) HFO technique. HFO successfully overcome HFCs' shortage of high GWP, however, due to its high price and insufficient supply will limit its popularization and application in the future several years in China. Additionally, methyl formate is also a potential choice for alternative.

0.2.3 Un-intended emission trend of HFC-23

The HFC-23 (CHF₃) is generated inevitably as a by-product during the manufacture of HCFC-22. Without commercial application, HFC-23 is abandoned directly into the atmosphere during the HCFC-22 production process.

HCFC-22 is used as a refrigerant in several different applications, as a blend component in foam blowing that is ODS application; and as a chemical feedstock is used manufacturing fluoropolymers such as tetrafluoroethylene (TFE). The ODS applications of HCFC-22 would be partly phased out from 2013, and phased out 97.5% of the baseline level by 2030 according to the requirement of Montreal Protocol. The feedstock application would be increased continuously with the development of economy and the expansion of the applications. The increase account of feedstock application may be more the reducing account of ODS application so that the production of HCFC-22 could be increased continuously, which results the increasing of emission of HFC-23.

If no control policy were implemented, it is predicted that HFC-23 emission will reach 30000 tons, which is 447 MtCO₂eq, by 2050 in China⁵.

⁵ GWP of HFC-23 accounted as 14800

0.3 Potential emission reduction analysis in mobile air-conditioner sector (HFC-134a)

Nowadays, HFC-134a is used as the refrigerant in mobile air -conditioner (MAC) in the world, especially for cars. The growth speed for global HFC-134a concentration is 3.8%-4.1% per year . Mobile air -conditioner industry consumes most HFC -134a. The industry is growing fast in recent years and it will keep on growing in the near future. Usually a mobile has a long lifetime, and the emission of refrigerant is delayed after consumption. It is estimated in early research paper (Hu, 2009) that the consumption and emission of HFC -134a of China in 2005 is 10139 and 7321 ton, respectively (105 thousand tons CO₂eq).

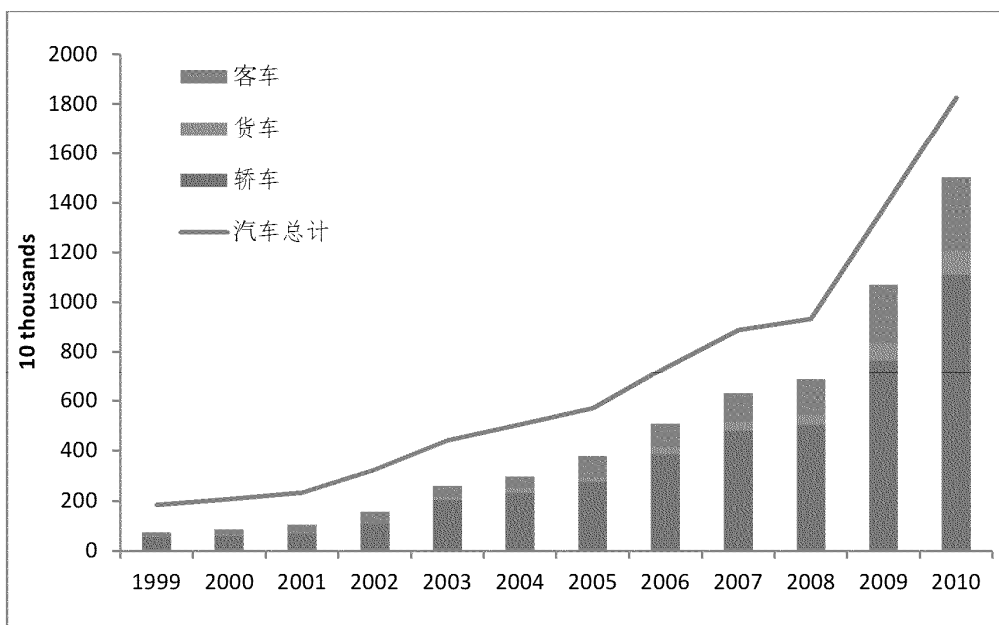


Fig. 6 Production of Total Mobiles and Mobiles with MAC in China

The business-as-usual scenario (BAU) and controlling scenario were set in this research. In the BAU scenario, the use of HFC -134a in MAC will not be restricted by Kyoto Protocol. In the controlling scenario, some assumptions were made: 1) the technology of servicing is not promoted, as well as the policy; 2) the controlling schedule is set with the international mobile industry and the policies of developed countries.

The lifetime of MAC contains four processes, namely, initial emissions, operational emissions, servicing emissions and end-of-life emissions. Major direct and indirect emissions were covered in our research.

The cost of controlling HFCs is extensive. The cost refers to incremental cost of the actives during the phase out of HFCs (compared with BAU scenario), including alternatives, alternative technique cost, equipment transforming cost, operational cost and publicity and training cost.

0.3.1 Forecast of car possession in China

China's auto industry has gone through decades of development, with increasing production capacity and product quality. In 2002, 2003, 2004, the production broke through the annual output of three million, four million, and five million, respectively. In 2005, China's auto market remains a moderately fast growth in fierce competition market, with production and sales reached 5.707 million and 5.758 million, respectively, and the growth is 12.56% and 13.54%, respectively. In 2007-2009, China's auto production reached 8.88 million, 9.35 million and 13.79 million (China Statistical Yearbook, 2010), and sales in 2010 reached 18 million. The percentage of cars with air-conditioner in China is 100%, about 30% for truck, about 75% for buses.

The study selected three indicators of GDP, population and disposable income of urban residents, and other factors affecting the demand for cars. Based on the mobile demand forecast models and parameters predictive value to predict the demand for cars in the next few years, the results are shown in the following table.

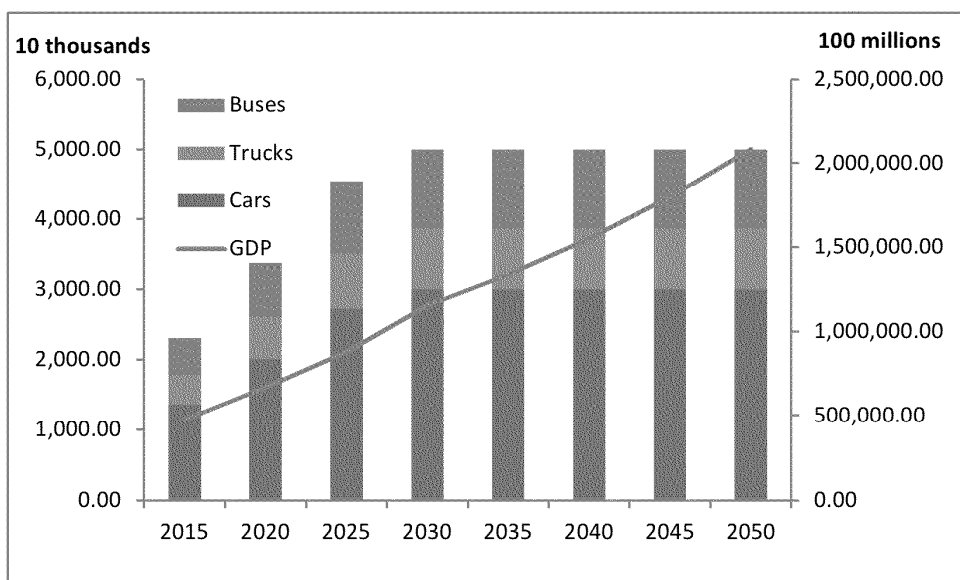


Fig. 7 Forecast of different kinds of vehicles in China for 2011-2050 (in 10 thousands)

According to the estimates of Association of Mobile Manufacturers, the peak capacity in the Chinese automotive industry will reach 50 million per year, and the car ownership could be over 200 million. Therefore considers that the Chinese automotive industry's largest annual demand for 50 million s vehicle production is maintained at the level of the maximum capacity remains unchanged since 2027. In this scenario, China 2015, 2020, 2030, 2040 automotive a thousand persons of car ownership would reach 120.3, 201.5, 378.7, 441.2 cars. As the auto demand reach saturation, it would maintain the level of 2040 in 2050. This scenario is consistent with the general level of the world.

For the refrigerant charging during vehicle production, the emission rate is 0.5% of charge size (IPCC, 2006), while the charge size for different vehicles is different. Repairing and re-filling volume are also mentioned in the IPCC report operational emissions, including all in-service automotive air conditioning maintenance after the leak of the running process, usually supplementary refillable. Operational emissions equal to the amount of maintenance supplementary refillable.

It is expected that China's mobile production continued to grow from the current level of 18 million to the 2030 level of about 50 million. At present, China's auto consumes about 21,000 tons HF C-134a in charging, and about 16 ,000 tons for the maintenance refillable; the annual total consumption is about 37,000 tons.

0.3.2 Emission reduction potential analysis of HFC-134a

Based on the future demand for mobiles forecasted with existing data, the following research and analysis were conducted: (1) control ling of HFC-134a trends and the availability of alternative technologies designed in accordance with the current international scene controlling HFC -134a; (2) according to the design scene under different scenarios HFC -134a analysis calculated the cost of diff erent environmental benefits of HFC-134a of the environmental benefits and environmental benefits; (3) the cost of different environmental benefit based on cost analysis.

For BAU scenario, the situation of that there is no need for China's automotive industry to phase out HFC -134a can be assumed and HFCs consumption is calculated as follows.

Table 2 Key parameters in BAU scenario

	Emission	Source and references
Producing MAC with existing technique		Existing policies
Manufacturing technique and emission maintain unchanged	0.5%	IPCC default emission factor (IPCC, 2006)
Using HFC -134a as refrigerant	Initial emission is 0.5%, Operational and servicing emission is 20%	IPCC default emission factor
Recycle	No recycle, 80% of refrigerant remained	There no regulations in China to promote refrigerant recycle, the remained amount was assumed in our report

Elimination scenarios were set based on (1) China's 2020 emission reduction targets; (2) the phase -out of HFC-134a in the EU, led by the Act (Directive 2006/40/EC); (3) the US-led Montreal Protocol amendment, direct emission reduction for HFC -134a, which is the future development of the accelerated phase -out of HFC-134a may have a fundamental change in the near future, this assumes that the phase-out scenario is as follows:

Table 3 Design of controlling scenario

	Control	information source
controlling scenario A (S-A)	Begin in 2016 and finish in 2020, linearly within 2016-2020	According to the reduction target of China in 2020. HFC-134a is one of controlling gas. It is the most extreme situation.
	Using HFO-1234yf as alternative	Assumption, according to the developed countries.
	Using HFC-152a as alternative	Assumption, partial alternative have similar GWP
controlling scenario B (S-B)	Begin in 2021 and finish in 2030, linearly within 2021-2030	10 years later than EU F-gas regulation
	Using HFO-1234yf as alternative	Assumption, according to the developed countries.
	Using HFC-152a as s alternative	Assumption, partial alternative have similar GWP
controlling scenario C (S-C)	Begin in 2018 and finish in 2034, linearly within 2018-2034	MP abatement proposed by the North America countries for developing countries
	Using HFO-1234yf as alternative	Assumption, according to the developed countries.

	Using HFC-152a as alternative	Assumption, partial alternative have similar GWP
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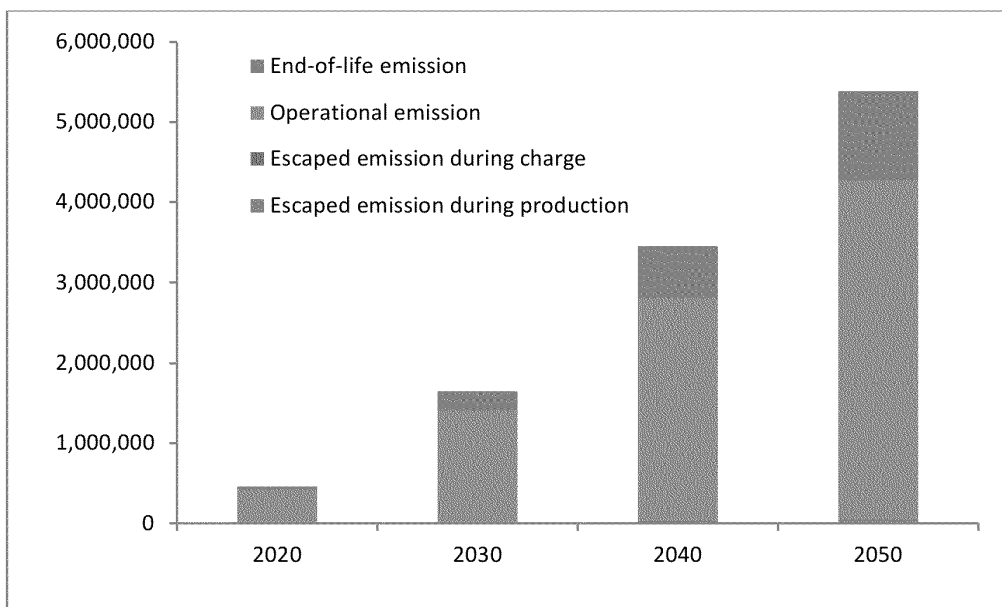


Fig. 8 Estimated Emissions in BAU (ton)

From 2011, due to the production of HFC -134a, emissions from the emissions of the chemical companies and the initial filling of the proportion is less than 0.94% and 0.46%, respectively, and the proportion is declining; while operational emissions (maintenance demand) has been accounted the highest proportion of nearly 95% in 2011, and the proportion will decrease to 74.5% in 2050; And because of the increasing of scrapped cars, the proportion of end -of-life process emissions continue to increase from less than 5% in 2011, to more than 24.9% in 2050. The data shows that reducing the leakage rate of the operational process holds the maximum emission reduction potential.

As can be seen from Table 35, whether using HFC -152a or HFO -1234yf, the cumulative emission reduction of GHG of Scenario A, Scenario B and Scenario C in 2050 will reach 2.6 -3.5 billion tons of CO₂eq and 2.9 -4.0 billion tons of CO₂eq, respectively.

However, different working fluid will have different fuel consumption during the operation of MAC. If the alternative refrigerants energy efficiency than HFC -134a, and the GWP value lower than HFC-134a, they will reduce GHG emissions obviously.

But when the alternative refrigerants, energy efficiency is lower than HFC -134a, will bring additional fuel consumption negatively effective. Seen by the following diagram, the change in air-conditioning working fluid, cooling efficiency is reduced to 5%, the emissions HFC -134a the benefits of higher than about the additional energy consumption with the negative impact of only from the angle of the environmental benefit is still positive benefit. But when the 10% increase in energy consumption, the benefits of emission reduction HFC-134a is not enough to offset the additional energy consumption with a negative impact, only from the perspective of the environmental benefits of negative effective. This does not include the influence of the other pollutants caused from the additional fuel consumption, such as NO_x, PAH.

Table 4 HFCs emissions and GHG emission reductions of different scenarios

	Emission (ton)						GHG reduction (million ton CO2eq)							
	HFC-134a				HFC-152a or HFO-1234yf				GHG reduction (HFC-152a)			GHG reduction (HFO-1234yf)		
	BAU	S-A	S-B	S-C	S-A	S-B	S-C	S-A	S-B	S-C	S-A	S-B	S-C	
2015	41252	41252	41252	41252	0	0	0	0	0	0	0	0	0	
2020	74852	41845	74852	64351	33006	0	10501	41	0	13	47	0	15	
2025	114044	31933	75983	66007	82111	38061	48037	102	47	60	117	54	69	
2030	152986	0	54851	50726	152986	98135	102260	192	122	127	218	140	146	
2035	180961	0	7565	31828	180961	173397	149133	227	217	187	258	247	213	
2040	193555	0	0	22286	193555	193555	171269	243	243	215	276	276	244	
2045	193555	0	0	8734	193555	193555	184821	243	243	232	276	276	264	
2050	193555	0	0	383	193555	193555	193172	243	243	243	276	276	275	
cumulati ve total 2020	457673	368877	457673	439702	88796	0	17971	110	0	22	127	0	26	
cumulati ve total 2030	1646051	624670	1181916	1078496	1021381	464135	567555	1272	576	705	1456	662	809	
cumulati ve total 2040	3453024	624670	1328373	1394889	2828354	2124651	2058135	3540	2656	2574	4033	3030	2935	
cumulati ve total 2050	5388575	624670	1328373	1483045	4763905	4060202	3905530	5974	5089	4895	6793	5790	5569	

0.3.3 Cost-benefit analysis

Taking both scenario A and B will be bring the change of cost probably, which will include the production of automotive air -conditioning business equipment modification, the manufacturing cost of the air conditioner (pipe, refrigeration, etc.), running costs (fuel consumption and air conditioning maintenance). Refrigeration systems to HFC -152a and HFO -1234yf and HFC -134a refrigeration system close to this study ignores the equipment modification, the manufacturing cost of non-air-conditioned the refrigerant part of cost. The calculation mainly includes the changes of refrigerant price and the changes of fuel consumption.

Table 5 Estimated emissions and mitigation cost for different scenarios

	S-A(HFC-152a)	S-B(HFC-152a)	S-C(HFC-152a)	S-A(HFO-1234yf)	S-B(HFO-1234yf)	S-C(HFO-1234yf)
GHG reduction emission (million ton CO2eq)						
cumulative total 2020	104	0	21	127	0	26
cumulative total 2025	464	111	206	564	135	250
cumulative total 2030	1207	545	667	1456	662	809
cumulative total 2035	2233	1386	1465	2675	1674	1761
cumulative total 2040	3381	2532	2456	4033	3030	2935
cumulative total 2045	4549	3700	3531	5413	4410	4210
cumulative total 2050	5717	4868	4681	6793	5790	5569
Increasing Cost(10000 RMB)*						
cumulative total 2020	1181448	0	228184	1529886	0	299664
cumulative total 2025	4495886	973837	1906872	5772644	1268365	2461346
cumulative total 2030	9144477	4096362	5163918	12587094	5277865	6723949
cumulative total 2035	13445207	8310239	8700126	19942517	11338216	12451304
cumulative total 2040	16978261	11846062	11823188	26380283	17761845	18007664

cumulative total 2045	19741046	14608847	14495132	31510678	22892241	22738879
cumulative total 2050	21905760	16773561	16662910	35530477	26912040	26696263
Reduction cost per unit(RMB/ton CO2eq)*						
average in 2020	113	-	108	121	-	117
average in 2025	97	88	93	102	94	98
average in 2030	76	75	77	86	80	83
average in 2035	60	60	59	75	68	71
average in 2040	50	47	48	65	59	61
average in 2045	43	39	41	58	52	54
average in 2050	38	34	36	52	46	48

note* : discount rate 5%, same with others in this report.

Using HFO-1234yf as the alternative refrigerant will reduce the most GHG emissions, considering the manifestation rate of 5%, the abatement costs per unit of three scenarios (using HFO-1234yf) are gradually reduced, the average cost of reducing emissions in 2050 are 52,46 and 48 yuan per ton of CO2eq, respectively, and scenario B holds lowest abatement costs. Using HFC-152a will not increase the cost of vehicles, because the price is lower than of the working fluid in HFC-134a, HFC-152a but will reduce costs; to mobile fuel consumption will increase the cost of the operation, with the continuation of the alternative time unit of emission reduction. When this will gradually reduce, and ultimately to the 2050 average abatement costs were 38,34 and 36 yuan per ton of CO2eq, respectively, in which scenario B the next lowest average abatement cost. As HFO-1234yf prices are still relatively high, if it is assumed that since 2016, the price of HFO-1234yf reduced to 2025 by 30% of the original price linearly, and then remains unchanged, the average reduction by 2050 the exhaust cost could be reduced to 30 yuan per ton of CO2eq, having a significant price advantage compared with HFC-152a. It can be speculated that if the price of the working fluid HFO-1234yf can be reduced, and maintenance requirements can be reduced, using HFO-1234yf to replace HFC-134a will have the largest emission reductions and the least abatement costs, which is an ideal scenario in the future.

0.3.4 Conclusion

China's auto industry will continue to grow, according to the regression model, it is expected that the demand for cars in China in 2030 will reach a maximum production capacity of 50 million, could be accompanied by growth in automotive air conditioning, subsequent to the 2050 mobile demand remained unchanged; under the baseline scenario, consumption of HFC -134a is expected to reach 20 million tons in 2050, of which 30% for the initial filling of new vehicles, 70% for maintenance reperfusion. From the consumer point of view, HFC -134a consumption equivalent to 292 million tons of CO₂eq; emissions, compared with 277 million tons CO₂eq, which is currently the largest emission reduction potential scenarios.

Beginning at 2016 to control and to phased out in five years linearly (no corresponding GHG emission reduction in 2015), using of different alternative technologies, it is expected that accumulated GHG emissions can reach 0.10 -0.12 billion tons by 2020, and in 2050 it can be 5.71 -6.79 billion tons; If controlling HFC-134a from 2021 and phasing out HFC -134a in 10 years linearly, different alternative technologies is expected that by 2050 cumulative reduction GHG emissions 4.87-5.79 billion tons; linear phase-out of HFC-134a in 27 years starting in 2018 to control HFC -134a, different alternative technologies is expected can be accumulated by 2050 to reduce GHG emissions 4.68-5.57 billion tons.

Using HFC-152a will reduce the cost of initial filling in mobile manufacturing process, and will also reduce the cost of automotive air conditioning repair process refillable refrigerant; however, reduce energy efficiency will lead to increased fuel consumption of automotive air conditioning is running, it produced an additional automotive air conditioning operational fuel consumption costs and additional CO₂ emissions, the integrated refrigerant cost reduction and an increase in fuel cost, alternative incremental costs accumulated to 166.6 -219.0 billion yuan in 2050, under the discount rate of 5%.

Using HFO-1234yf will increase the costs of the initial filling of the mobile manufacturing process, and will also increase the cost of the automotive air

conditioning repair process refrigerant refillable; However, due to energy efficiency and HFC-134a is close to, the automotive air conditioning running fuel consumption constant, does not produce additional CO₂ emissions, alternative incremental costs accumulated to 267.0-355.3 billion yuan in 2050, under the discount rate of 5%.

Under different scenarios, abatement cost per unit of CO₂ is 117-168 yuan / ton CO₂eq, compared to the current price of CO₂ emission reduction CDM project (\$10/t CO₂eq). If there are no technical improvements to decline the price of alternative technologies, the case CO₂ abatement costs of different contexts units are significantly higher than the prices of CO₂ emission reduction of CDM project. Therefore, strengthening the tightness of the automotive air conditioning to reduce maintenance requirements and to reduce the price of the alternatives at the same time is very important for the future.

0.4 Potential emission reduction analysis in residential air conditioner sector (HFC-410A)

China is the world's largest producer and consumer of residential air conditioner (RAC). The Chinese production accounts for 75% of the global totals. The industry's annual output value is about 230 billion Yuan. Due to China's fast economic development and population growth, the future demand of as well as emissions of these will increase accordingly. Refrigerant HFC -410A is a mixed blend of HFC -32 (50%) and HFC-125 (50%).

0.4.1 Estimates of future demand of RAC

Statistical analysis reveals significant correlations between the annual demand of residential air conditioner and the GDP, urbanization level, population, and urban residents' disposable income, respectively. Based on mathematical model and the forecast of variables (urbanization level was chosen in this report) for 2010 -2050, annual demands for residential air conditioner were estimated for the next decades. The results are shown below.

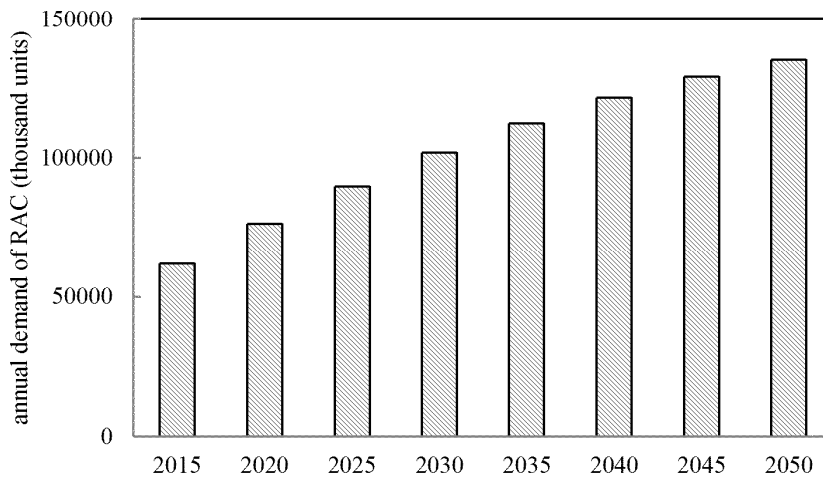


Fig. 9 Estimated domestic annual demand of RAC (thousand units) during 2012-2050

Total demand of refrigerant includes filling consumption for new product filling, consumption for maintenance and transport loss.

BAU scenario: In this report, it was assumed that HFC -410A replaces HCFC-22 in RAC sector within 20013-2015. Prior to 2012, some proportions of RAC have used HFC-410A as refrigerants (most are inverter air conditioner). A recent market survey reveals that there are near 99% of the household inverter air conditioner using HFC-410A as refrigerant. After 2013, HCFC -22 consumption is constrained by the Accelerated HCFCs Phase Out Agreement made by MP parties. The allowable HCFC amounts are used to meet the maintenance needs first, then the needs of new filling. When the quantity of new RAC using HCFC -22 is smaller than the number of domestic RAC demand, HFC -410A is used as refrigerants. HFC -410A consumption under the BAU scenario is shown as follows.

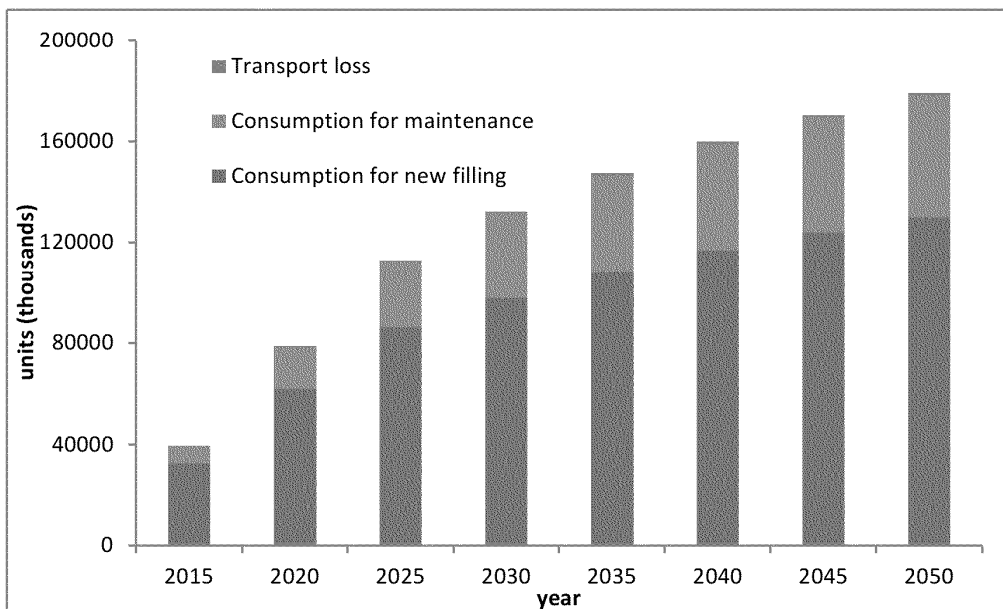


Fig. 10 Projected Annual HFC-410A consumptions in RAC sector within 2010-2050

Alternative scenarios: considering of coming requirement of GHG emissions reduction within 2013 -2050 period, high -GWP substances should be gradually replaced by the low-GWP or 0-GWP alternatives. Considering the development of the refrigerants in RAC sector, this report assumed that HC -290 or HFC -32 alternatives will replace HFC-410A. Different phase-out scenarios are shown table below.

Table 6 Definition of different alternative scenarios

Alternative scenarios	Definition
A-HC290	HC-290 as Alternative. Time table in proposed amendment to the Montreal Protocol by three North American countries.
A-HFC32	HFC-32 as Alternative. Time table in proposed amendment to the Montreal Protocol by three North American countries.
B-HC290	HC-290 as Alternative. Five years delay after time table in proposed amendment to the Montreal Protocol by three North American countries. That means HFC410A consumption limit starts in 2023. Frozen level (also five year delay) is average of consumption in 2010-2013.
B-HFC32	HDC-32 as Alternative. Five years delay after time table in proposed amendment to the Montreal Protocol by three North American countries. That means HFC-410A consumption limit starts in 2023. Frozen level (also five year delay) is average of consumption in 2010-2013.
C-HC290	HC-290 as Alternative. Since 2013, originally required 50% of HFC-410A for filling new RAC is replaced by HC-290, and time table in proposed amendment to

	the Montreal Protocol by three North American countries is adopted.
C-HFC32	HFC-32 as Alternative. Since 2013, originally required 50% of HFC-410A for filling new RAC is replaced by HFC-32, and time table in proposed amendment to the Montreal Protocol by three North American countries is adopted.
D-HC290	HC-290 as Alternative. Since 2013, originally required 50% of HFC-410A for filling new RAC is replaced by HC-290.
D-HFC32	HFC-32 as Alternative. Since 2013, originally required 50% of HFC-410A for filling new RAC is replaced by HFC-32.

The calculated amounts of RAC filling with HFC -410A or other as refrigerant under Alternative scenarios are shown in table below.

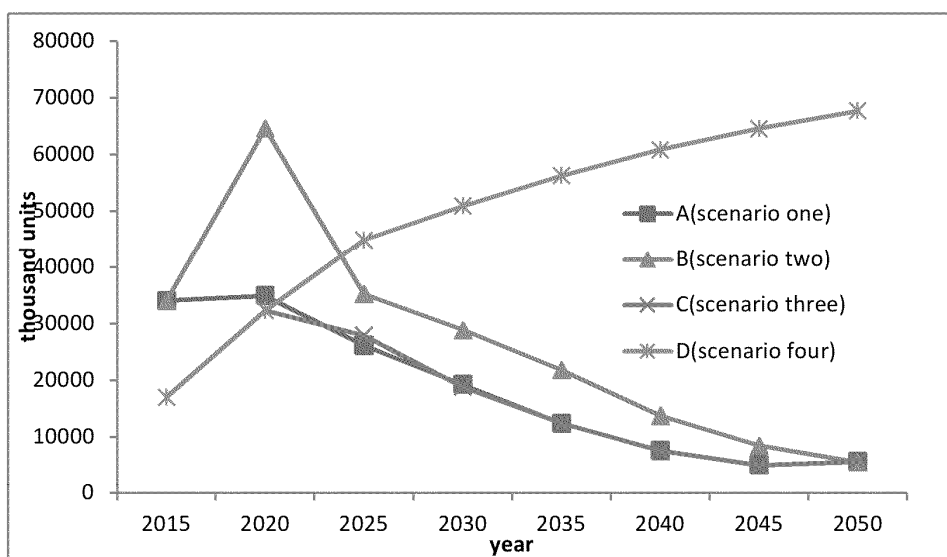


Fig. 11 The projected amounts of RAC filling with HFC-410A as refrigerant under alternative scenarios (thousand units)⁶

0.4.2 Emission calculation for RAC sector

According to the IPCC/TEAP Special Report (2005), the features of the Chinese RAC sector, as well as actual surveys and expert suggestions, we determined the emission calculation mechanism and emission factors to calculate emissions. Initial emission rate was set to 0.6%; annual emission rate was set to 3%; residual refrigerant in the end-of-life was set approximately to 75% of the initial fill. The average service

⁶ HCFC-22 is not included, as quantities of RAC filled with HCFC-22 are the same in each scenario.

life of the Chinese residential air conditioner was set to 10 years; and every year there are some proportions for maintenance and retirement.

Parameters for calculations are shown in the table below.

Table 11 Calculation parameters for RAC sector

Items	Values
Life time of RAC ^a	10
Annual emission rate ^b	3%
Maintenance emission rate ^b	100%
Retirement emission rate ^b	75%
Average filling volume of HCFC-22 in each RAC ^c	1.2kg
Average refilling volume of HCFC-22 in each RAC ^c	1.2kg
Average filling volume of HFC-410A in each RAC ^c	0.96kg
Average refilling volume of HFC-410A in each RAC ^a	0.96kg
Average filling volume of HC-290 in each RAC ^c	0.6kg
Average refilling volume of HC-290 in each RAC ^c	0.6kg
Initial emission rate ^b	0.6%

Note : ^a derived from survey by China Household Electrical Appliances Association;

^b derived from IPCC (2006);

^c derived from residential air conditioner industry HPMP

BAU scenario: the following figure shows HFC -410A annual consumption and emissions under BAU scenario. It reveals that HFC -410A annual emissions are lower than annual consumption, especially in the 2013 -2030 periods, which is due to the delay between consumption and emission in RAC sector. When annual sales of RAC have a steep growth, emissions could be significantly lower than consumption. Over time, HFC -410A, the emissions could be gradually close the HFC -410A annual consumption.

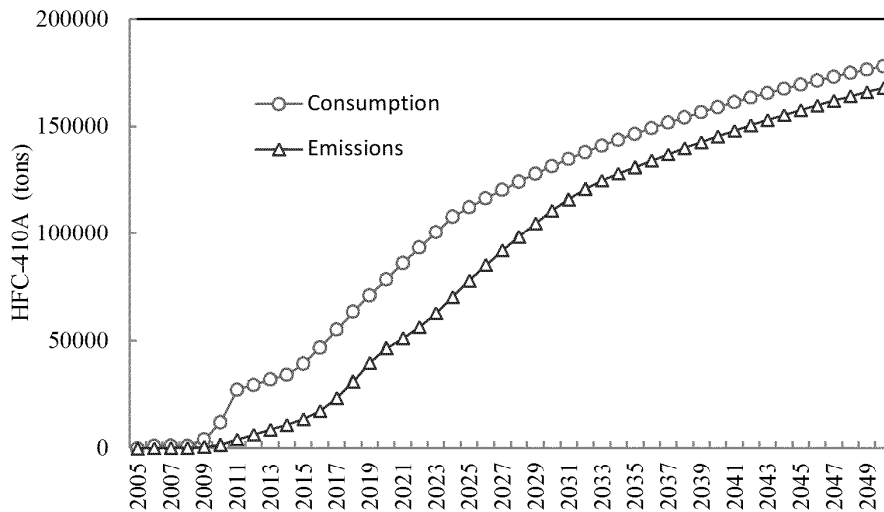


Fig. 12 Projected HFC-410A annual consumptions and emissions within 2005-2050 under BAU scenario

Alternative scenarios: trends as well as peak year of emissions of HFC -410A emissions are different under different scenarios. Under D -HC290 or D -HFC32 scenarios, emissions of HFC -410A will increase year by year, to 84,038 tons in 2050. Under A-HC290 or A -HFC32 scenarios, the growth rate of emissions of HFC -410A after 2018 is smaller than that under the BAU scenario. Under B -HC290 or B-HFC32 scenarios, after 2023 the growth rate of emissions of HFC -410A will be smaller than that under the BAU scenario; the highest emissions are in 2028. Under C -HC290 or C-HFC32 scenarios, the growth rate of emissions of HFC -410A after 2013 could be smaller than that under the BAU scenario; the highest emissions are in 2029.

The total emissions of refrigerant (including HCFC -22, HFC -410A, HC -290 or HFC -32) are not the same under different Alternative scenarios. Emissions will reach a peak and then begin to decline under A, B, C scenarios, while under D scenarios, the total emissions continue to increase, and eventually reach about half of those under BAU scenario. Total emissions under scenarios using HFC -32 as alternatives could be significantly higher than those in the counterpart scenarios using HC -290 as alternatives.

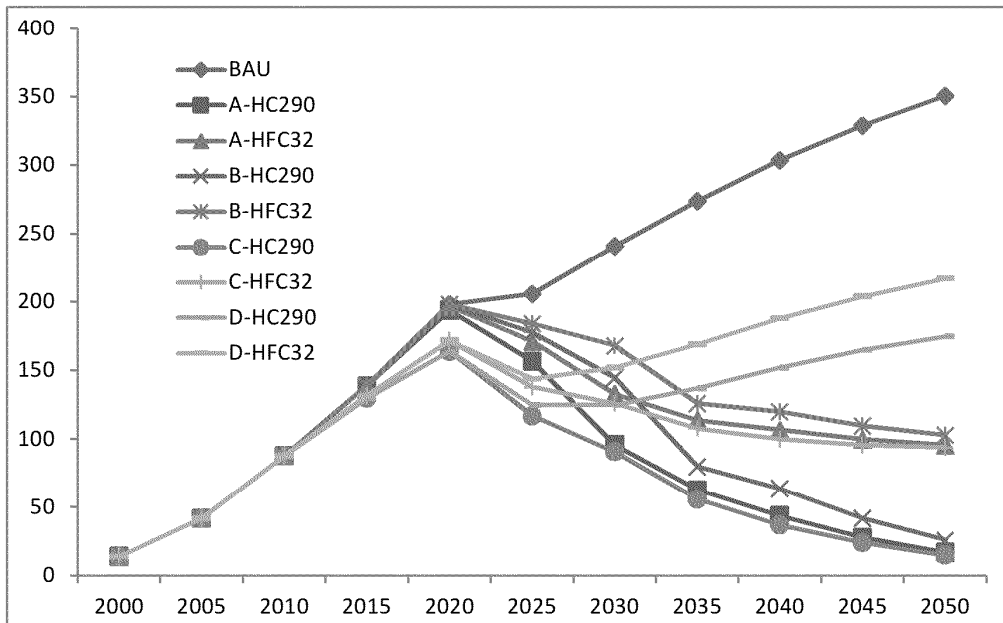


Fig. 13 Projected annual emissions of refrigerant under different scenarios (million tons CO₂eq)

0.4.3 Cost-Benefit Analysis

Cost-benefit calculation: the cost of phasing out HFCs in the residential air conditioner sector includes the fees of introducing new technologies by manufacturers, incremental investment for replacing the production line (including the replacement of the new refrigerant filling machines and other equipment), fees for new refrigeration agent/blowing agent, a lubricant, later purchasing new compressors which are able to withstand the higher pressure, and incremental operation cost.

Table 7 Parameters of calculating fees of phasing out HFC-410A in RAC sector

Items	Values
A production line capacity (10 thousands) ¹	25
Cost of converting to HC-290 production line (10 thousands Yuan/production line) ¹	2,080
Cost of converting to HFC-32 production line (10 thousands Yuan/production line) ¹	0
Incremental cost of production of HC-290 air conditioner costs (Yuan/unit) ¹	91
Incremental cost of production of HFC-32 air conditioner costs (Yuan/unit) ¹	61.8

Price of HCFC-22 (Yuan/Kg) ²	18
Price of HFC-410A (Yuan/Kg) ²	70
Price of HC-290 (Yuan/Kg) ²	20

Note : ¹ derived from survey by China Household Electrical Appliances Association;

² derived from market survey.

Here we present the annual environmental benefits, including climate mitigation, energy saving and pollutant reduction.

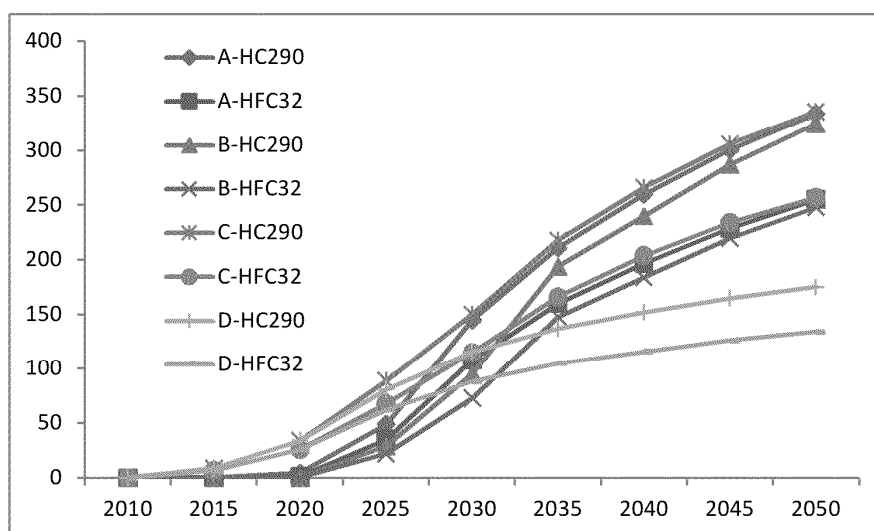


Fig. 14 Projected emission reductions under each scenario in RAC sector (million tons CO2eq)

Emission reductions resulting from HFC -410A phase out in RAC sector are shown in figure above. Before 2012, emission reductions are zero, because it is assumed that refrigerants in new residential air conditioner are replaced by HFC-410A from 2013. In 2013, emission reductions under C -HC290 and D -HC290 scenarios are 2.2 million tons CO2eq, while emission reductions under the A -HC290 and B -HC290 are 0 million tons CO2eq. In 2018, emission reductions under A-HC290 scenario become positive, being 1.0 million tons CO2eq. In 2020, emission reductions are 4.5, 0, 34, 34 million tons CO2eq, respectively, under A - HC290, B-HC290, C -HC290 and D -HC290. In 2023, emission reductions under B -HC290 scenario become positive, being 9.5 million tons CO2eq. In 2030, emission reductions reach 145, 95, 150, 116 one million tons CO2eq under A - HC290, B -HC290, C-HC290 and D -HC290, respectively. In 2050, there are 334, 325, 336, and 175

Scenario 4-HC290

Scenario 3-HC290

Scenario 2-HC290

Scenario 1-HC290

million tons of CO₂eq emission reductions under A-HC290, B-HC290, C-HC290 and D-HC290.

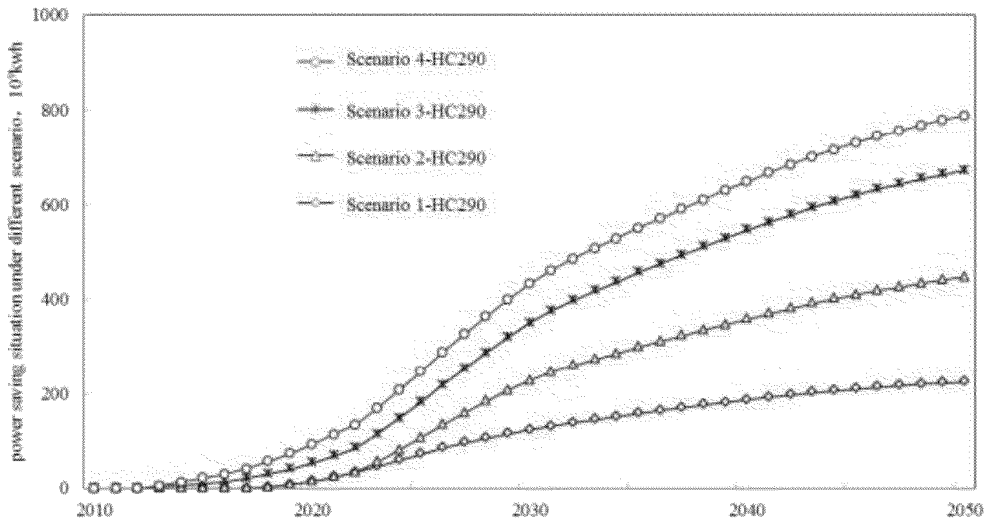


Fig. 15 The projected power savings for China's RAC sector under different scenarios (10⁹ kWh)

Electricity saving under all Alternative scenarios increases as the year. In 2013, electricity savings are 2×10^9 kWh under C-HC290 the D-HC290 scenarios. In 2020, electricity savings become 15×10^9 , 0×10^9 , 38×10^9 , 38×10^9 kWh under A-HC290, B-HC290, C-HC290 and D-HC290; the CO₂ equivalent emissions are 13, 0, 34, 34 Million tons. In 2050, under A-HC290, B-HC290, C-HC290 and D-HC290 the electricity savings are 225×10^9 , 223×10^9 , 225×10^9 , 117×10^9 kWh. During 2013-2050, cumulative electricity savings reach 1390, 1100, 1543, 1094 million tons CO₂eq in each Alternative scenario.

Due to electricity savings, pollutant emission reductions are also obtained in each Alternative scenario. Pollutant emission reductions increase yearly. Under scenario A-HC290, B-HC290, C-HC290 and D-HC290, respectively, environmental benefits

can reach emission reduction of 13.4×10^6 tons, 0×10^6 tons, 33.9×10^6 tons, 33.9×10^6 tons CO_2 ; 0.4×10^6 tons, 0×10^6 tons, 1.0×10^6 tons, 1.0×10^6 tons SO_2 ; 0.2×10^6 tons, 10^6 tons, 0.4×10^6 tons of 0.4×10^6 tons NO_x ; 3.6×10^6 tons, 0×10^6 tons, 9.1×10^6 tons, 9.1×10^6 tons dust. In 2050, pollutants emission reductions under A -HC290, B-HC290 and C-HC290 are very close, about 199×10^6 tons CO_2 , 5.9×10^6 tons SO_2 , 3.0×10^6 tons of NO_x , 53.6×10^6 tons dust. Pollutants emission reductions under D-HC290 are about 104×10^6 tons CO_2 , 3.1×10^6 tons SO_2 , 1.5×10^6 tons NO_x , 27.9×10^6 tons dust, which are about half of those reductions under A-HC290, B-HC290 and C-HC290.

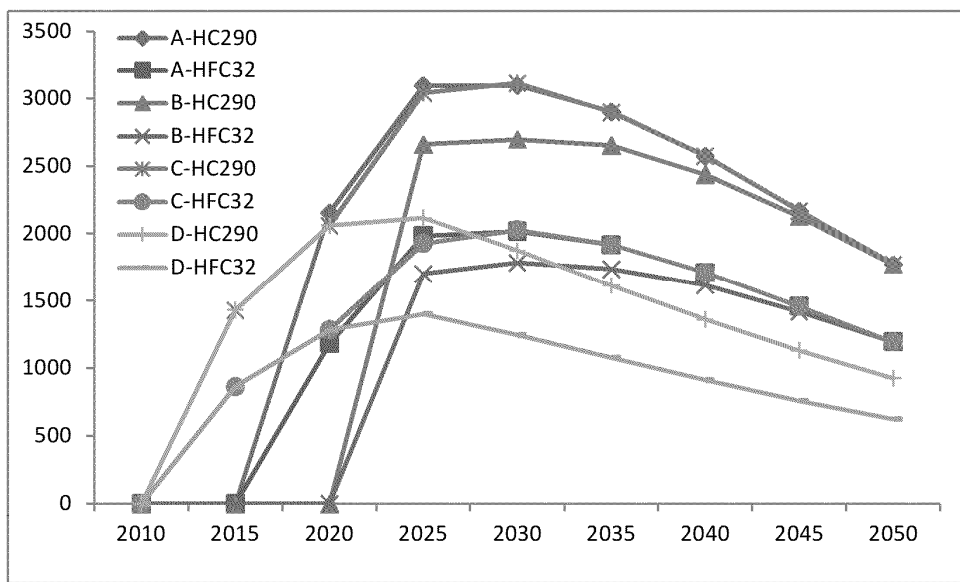


Fig. 16 Costs for phasing out HFC-410A in RAC sector for different scenarios (Unit: Million Yuan)

Incremental costs for phasing out HFC-410A in RAC sector are calculated based on following assumption . Currently there are no published cost data of converting HFC-410A RAC system to HC -290 or HFC -32 RAC system, therefore costs defined here are for converting HCFC -22 RAC system plus operating cost to HC -290 or HFC-32 RAC system and operating cost . Capital costs can be ignored when HFC-410A RAC production lines transform to HFC -32 RAC production lines. The above figure shows that the phase out costs experience first increasing and then decreasing trend (incremental investment costs decline over the years, while incremental operation costs increase at first and then decrease).

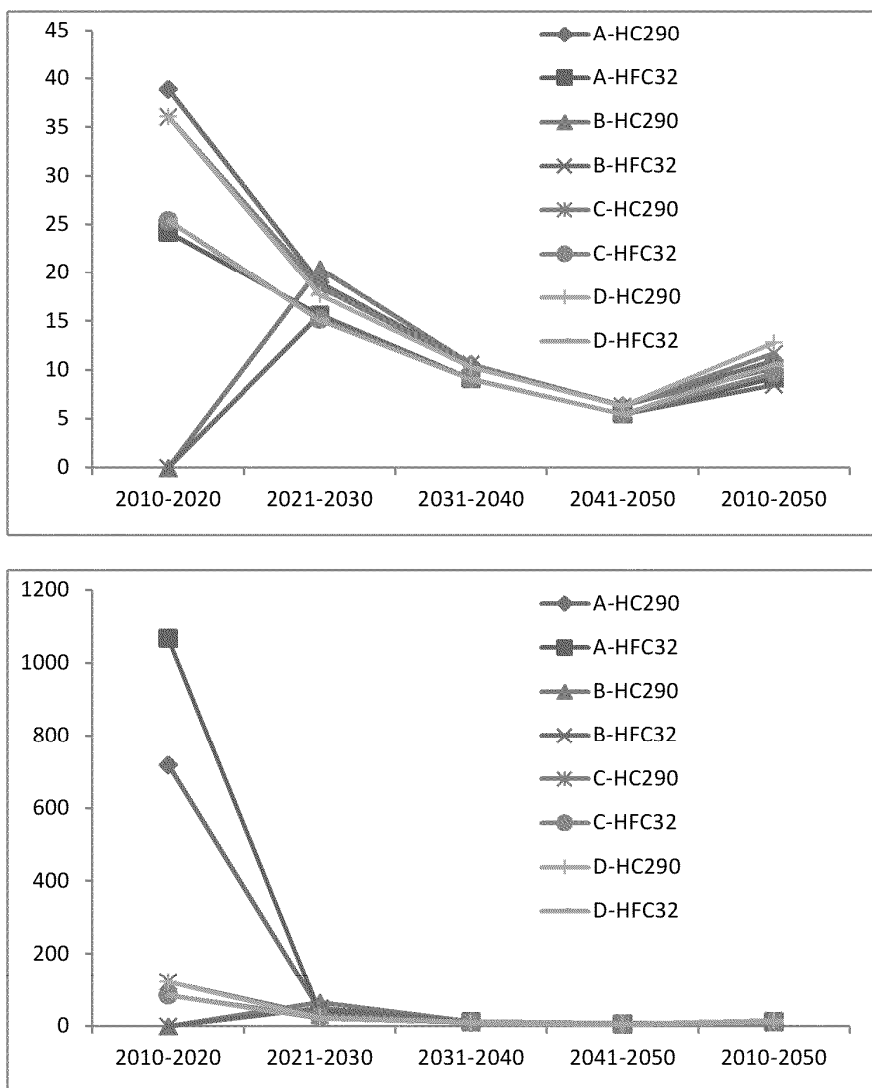


Fig. 17 Cost per consumption reduction (Yuan/ton CO₂-eq) (top panel) and Cost per emission reduction (Yuan/ton CO₂-eq) (bottom panel)

Due to the lag effect between the consumption and emissions of refrigerants in RAC, annually reduced consumption is not equal to reduced emission in the same year. For example under D-HC290 scenario, consumption reductions are 420 Mt CO₂eq within 2010-2020, while emission reductions are only 124 Mt CO₂eq. However, the annual investment will directly be reflected in the annual reduction of consumption not the emission reduction. Cost per consumption reduction keeps relatively stable, about 8-13 Yuan/ton CO₂-eq within 2010-2050. The previous stage of the investment will show effect by resulting larger emission reductions in the next phase-out stage. Accordingly, cost per emission reduction decrease rapidly. For

example under A -HC290 scenario, cost per emission reduction drops from 719.2 Yuan (2010 -2020) to 7.0 Yuan (2041 -2050). Under eight emission reduction scenarios, the average cost per emission reduction within 2010-2050 is very close, about 11-16 Yuan/ton CO₂eq, which the average cost per emission reduction under B-HFC32 scenario is the lowest, about 11.3 Yuan/ton CO₂eq, and this cost is highest under D-HC290 scenario, about 15.7 Yuan/ton CO₂eq.

0.4.4 Conclusion

To use HC -290 as refrigerants in RAC as much as possible will bring the maximum climate benefit. The efforts should be always made to implement HC -290 RAC instead of HFC-410A RAC or HFC -32 RAC. Under C -HC290 scenario, incremental costs are 29,330 million Yuan within 2021 -2030 period, which can reduce consumption by 1584 Mt equivalent CO₂ (cost per consumption reduction is 18.5 Yuan/ton CO₂eq) and reduce the emissions by 958 Mt equivalent CO₂ emission (cost per emission reduction is 30.6 Yuan/ton CO₂eq). This is a good cost-effect relationship.

To recovery, recycle and reuse HFCs as much as possible. According to electrical and electronic waste recycling and reuse management regulations and other laws and regulations, the waste recycling system for RAC and disposal system of the refrigerants should be established. If HFC -410A used as refrigerants, the emissions from retirement of the RAC and maintenance stages will reach 20,145 tons and 16,410 tons in 2020, equivalent to 42 Mt CO₂ and 34 Mt CO₂, accounting for more than 75% of the total emissions in that year. Previous studies estimated that the cost of HFC-23 abatement is 0.42-2.49 U.S. \$/ton CO₂. Although costs of recycling or destructing HFC-410A was not estimated, it is believed that recycling or destructing this part of HFC -410A emissions can reduce a considerable amount of GHG emissions and achieve a good cost-benefit relationship.

To reduce the filling amount of refrigerant by improvement of technology. In present report, 0.96 Kg was set as the average filling volume of HFC -410A in each RAC. With technology approaches, e.g. filling amounts reduce to 0.8 kg,

consumption and emissions could be reduced by 20% during the new product charge and servicing.

To encourage the development of alternatives. Establish encourage mechanisms for application of environmentally friendly alternatives. According to the principle of operational cost flexibility in Multilateral Fund, use part of the incremental costs to encourage application of environmentally friendly alternatives. For example, strengthen the security of the HC-290 RAC by overcoming the problems of flammability, expanding the application field of HC-290 RAC.

To include products using environmentally friendly alternatives in the government's green procurement catalog: after safety requirements are met, promote the sale and application of the HC-290 RAC. Support bulk purchases using HC-290 or other environmental friendly RAC.

To reduce leakage rate of RAC. Improve the tightness of RAC to reduce leaks of refrigerants during operation. In the case of annual leakage rate of 3% in this report, HFC-410A emissions will reach 9,824 tons in 2020, equivalent to 21 Mt CO₂ emissions and will reach 25,314 tons in 2040, equivalent to 53 Mt CO₂.

0.5 Potential emission reduction analysis in HCFC-22

production sector (HFC-23)

The HFC-23 (CHF₃) is generated inevitably as a by-product during the production of HCFC-22. HCFC-22 is used as a refrigerant in Room Air Condition sector and Industry and Commercial Refrigerate sector, as a blowing agent in foam sector and as a chemical feedstock for manufacturing fluoropolymers such as tetrafluoroethylene (TFE). The applications as refrigerant and blowing agent was ODS application that would be phased out by implementing Montreal Protocol. But HCFC-22 feedstock application would increase with the development of economy and the expansion of the applications, which result more HFC-23 was produced.

0.5.1 HCFC-22 Consumption and HFC-23 Emissions

Based on the requirement of consumption in the application sectors, the future production of HCFC-22 could be predicted and HFC-23 emissions can be calculated (see following figure). The annual production of PTFE increased at a relatively stable growth rate in recent years in China (from Statistical yearbook of China). ODS applications of HCFC-22 is predicted based on demand in different sectors under 《HCFC PHASEOUT MANAGEMENT PLAN IN CHINA》, in which, China will freeze the production and consumption of HCFCs at the baseline level in 2013 (the average level of 2009 and 2010), eliminate 10% of production and consumption of the baseline in 2015.

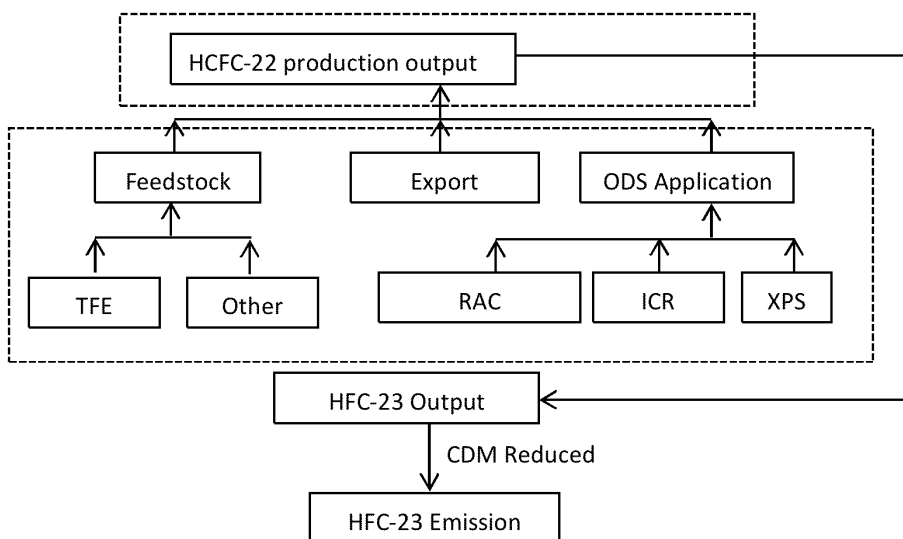


Fig. 18 Technical roadmap to predict production of HCFC-22 and emission of HFC-23

HCFC-22 is used as a chemical feedstock for manufacturing many fluorine fine-chemicals, mainly tetrafluoroethylene (TFE). Then TFE is mainly used as feedstock to produce PTFE and HFC-125, HFO-1234yf during 2010-2012.

Presently, there are 11 CDM projects for HFC-23 incineration being implemented in China, by which 5,611 tons/y of HFC-23 was disposed. Certified Emissions Reduction Units (CERs) for HFC-23 destruction account for 66.79 million

tons CO₂-eq per year, which cover 50% of HCFC-22 production (301.5 thousand tons). Because of the restriction not to certify reductions for new HCFC-22 facilities under KP's CDM, more than 50% of sum HFC-23, which from new production facilities, was illegible production for CDM and not processed and emitted into air directly in 2010 in China (see fig.16). The illegible production for CDM would be increased due to the HCFC-22 demand increased.

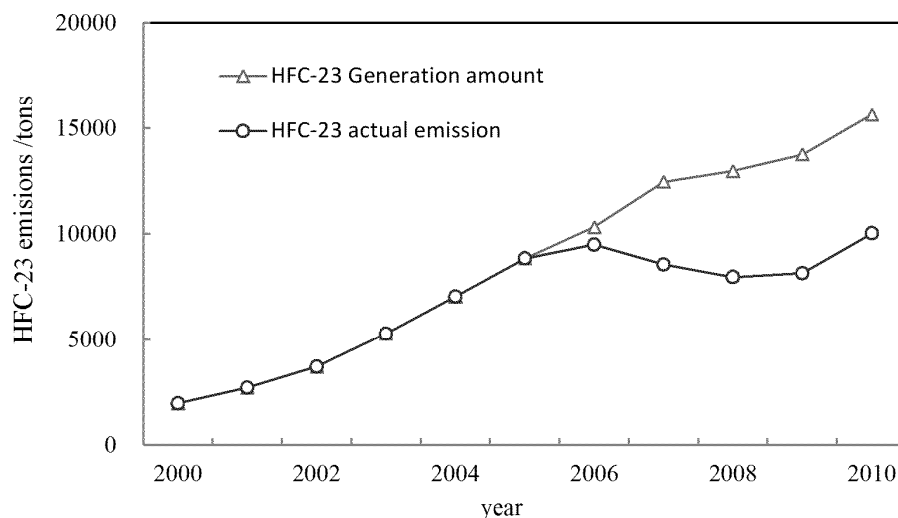


Fig. 19 Generation amount and actual emission of HFC-23 in 2000-2010

Without the CDM's HFC-23 projects, HFC-23 cumulative amount is about 1.11 billion tons CO₂eq, with an annual average increase rate of 24.7% from 2000 to 2010 in China. In 2010, the generation amount of HFC-23 was up to 15654 tons, equivalent to 231 MtCO₂eq. The implementation of CDM projects have come into operation since 2006, which realized a emission reductions of 20954 tons HFC-23, equivalent to 310MtCO₂eq from 2006 to 2010. Emission reductions accounts for 37.1% of the total emissions during the same period.

0.5.2 Emission Reduction Potential of HFC-23 in future

Under the Montreal Protocol, it is required to freeze production of HCFC-22 as ODS applications at average levels from 2009-2010 by 2013, cutting to 90% by 2015,

65% by 2020, 32.5% by 2025 of the baseline level and phase-out in 2030. Linear decreasing is assumed in each phase-out stage. The baseline was mainly to predict the production of HCFC -22 in feedstock application since it will continue to grow with no restriction.

HFC-23 emissions were calculated based on the future production of HCFC -22 and emission factors for each CDM projects. Based on current international negotiations, that CDM projects for HFC-23 not be decided to keep after 2012. Figure 17 showed the BASELINE of production of HCFC-22 and emissions of HFC-23.

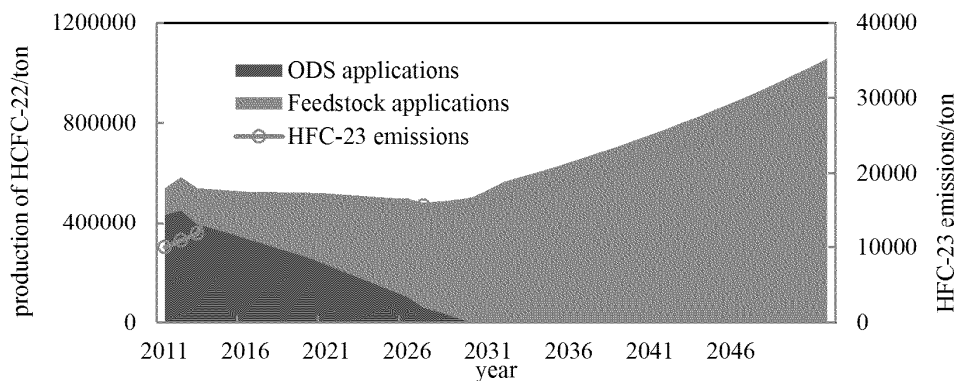


Fig. 20 Projected production of HCFC-22 and emissions of HFC-23

Scenario 1: to incinerate HFC-23. The equipment of 11 CDM projects would operate partly without foreign funding from 2013. It is assumed that the original equipment and technique with the support of the operation cost from government or other sources incineration rate of HFC -23 would rise linearly from 0 to 35%, that is the disposal rate of HFC-23 at 2010, from 2013 to 2020 and then rise linearly to 100% until 2050.

Scenario 2: keeping incinerate HFC-23. The all equipment of 11 CDM projects would be kept to operate entirely without foreign funding from 2013. It is assumed that based on the original equipment and technique with the support of the operation cost from government or other sources, HFC-23 incineration will keep to operation. It is presumed that incineration quantum of HFC-23 would be 5611 tons/year until 2020, and then rise linearly to 100% until 2040.

Scenario 3: Technology Optimization. Existing statistic data showed a relatively high emission rate of HFC -23, 3% is reported as the highest value by 4 enterprises which mean that the actual production rate is higher than the reported value. Most enterprises adopted 2% as the generation rate involving the application of a default emission factor of 1.5 % by one enterprise. A range of 1.5 -4 percent is probably more representative of current global operations. With technology optimization, emission factor can be lowered to 1.5%. (McCulloch and Lindley, 2007). It is assumed that lowering emission factor can be realized by means of strengthening the quality management and improving the design and techniques. The scheduled emission rate sustains from 2013 to 2020 at 2.85%, will be linearly lowered to 1.5% by 2040, and remain at this value after 2040.

Scenario 4: HFC-23 emission rate of Annex I countries was 2% in the 1990s as reported of UNFCCC and gradually declined to 0.9% in 2003 -2007. USEPA reported the HFC-23 emission rate of the US was declines from 1.36% to 0.76% during 2004 to 2010. USEPA assumed that under technology optimization, the emission rate will maintains at the lowest level of 0.76%. In this scenario, technology optimization feasibility is assumed. The scheduled emission rate will be linearly lowered to 2% by 2020, then linearly lowered to 0.76% by 2040, and remain at this value after 2040.

Cumulative emission reduction of each emission reduction scenario (1 to 4) is 551, 830, 166, 422 Mt CO₂eq from 2011 to 2020, and 7113, 8351, 3364, 6006 MtCO₂ from 2013 to 2050. Emission reduction of technology optimization scenario (emission rate is lowered to 0.76%) is close to that of the incineration scenario.

0.5.3 Conclusion

There are 16 production lines of 10 HCFC-22 production enterprises are operating CDM projects which reduce the HFC -23 actual emission through incineration. However, that CDM projects for HFC -23 not be decided to keep after 2012 according to current international negotiations.

The baseline was mainly to predict the production of HCFC -22, in which ODS applications would be phased out under "HCFC PHASEOUT MANAGEMENT

PLAN IN CHINA”, the feedstock application would increase with the development of China's economy and the expansion of the applications. HFC -23 emission would reach 30178 tons equivalent to 447 MtCO₂eq in baseline by 2050.

Cumulative emission reduction of each emission reduction scenario (1 to 4) is 551, 830, 166, 422 Mt CO₂eq from 2011 to 2020, and 7113, 8351, 3364, 6006 MtCO₂ from 2013 to 2050. Emission reduction of technology optimization scenario (emission rate is lowered to 0.76%) is close to that of the incineration scenario. The costs for the last two scenarios are not certain due to the complexity of Technology Optimization.

For emission reduction scenario selection, emission reduction of technology optimization scenario (emission rate is lowered to 0.76%) is close to that of the incineration scenario. However, incineration emission reduction scenario in future would be easily conducted when considering cost and technical requirement.

0.6 Opportunities and challenges of HFCs control

HFCs used as refrigerant, foaming agent, solvent, fire extinguishing agent, and so on; and they will be emitted after produced and applied if without recycle and destruction. And the emission of HCFC -23, which is the by-product of HCFC -22, needs to be paid attention to due to high volume. Based on the Montreal Protocol, developing countries started to phase out HCFCs from 2013 and to phaseout 97.5% of the HCFCs by 2030. HFCs as one of the main alternatives of ODS, the consumption and emissions of HFCs could be growing rapidly. It is very important to choose the right alternative of HCFCs to avoid the rapid growth of HFCs consumption then emission. It is both an opportunity and a challenge to the development of control and management of HFCs.

0.6.1 The consumption and emissions of HFCs in China

0.6.1.1 The prediction of the consumption and emissions of HFCs in China

Based on the current consumption trend and the development of related industry sectors, the consumption of HFCs in China will continue to grow rapidly in the near future.

HFC-134a

HFC-134a is one of the mainly used for mobile air conditioning, industry and commerce refrigeration /air conditioning and medical aerosol. Currently the mobile industry is the biggest consumption sector of HFC-134a; and the GWP of HFC-134a is 1430. China produces and consumes the largest number of mobile in the world after 2010. Automobiles have a long service life such as 10 years plus. Therefore, the emissions of HFCs will continue in a long period, even after automobiles retire entirely. With the development of economic and the growth of population, Chinese auto output is likely to be increased from the current 18 million vehicles per year to about 26 million in 2020. Following the current international, the analysis predicts that, the consumption of HFC-134a would be up to 50,000 tons in 2015, which equals to 70 million tons CO₂eq under the BAU scenario; and the emissions of HFC-134a would be up to 35,000 tons in 2015, which equals to 50 million tons CO₂eq. The consumption of HFC-134a would be up to 80,000 tons in 2020, which equals to 100 million tons CO₂eq; and the emissions of HFC-134a equals to 80 million tons CO₂eq in 2020. It is very important that the consumption and emission of HFC-134a would be increased faster due to high demand of servicing after 2020.

HFC-410A

HFC-410A, made by mixing HFC-125 and HFC-32, is mainly used for residential air conditioning, industry and commerce refrigeration; and the GWP of HFC-410A is 2088. China produces and consumes the largest number of residential air conditioner in the world. Its annual production has taken nearly 75 % of the total global output, and the total output of the residential air conditioner industry was 230

billion RMB. With the development of economic and the growth of living standard, China needs more and more residential air conditioner, and the consumption and emissions of HFCs is increased accordingly if without actions. The analysis predicts that the consumption of residential air conditioner would be 5,932 million sets in 2015, and be increased to 7,332 million sets in 2020. According to the Montreal Protocol, if HFC-410A used as alternative to replace HCFC-22 entirely in this sector, the total aggregate demand of HFC-410A would be 33,000 tons in 2015, and be increased to 81,000 tons in 2020 that equal to 233 million tons CO₂eq. Therefore low GWP products, such as R-290, can be used to avoid and reduce the demand of HFC-410A.

HFC-245fa

HFC-245fa is mainly used for foam industry, and the GWP value is 314. Based on the foam industry scheme, Climate Neutral (HC) technology is the main alternative technology to reduce the usage of HFC-245fa. Under the uncontrolled scenario, if we use HFC-245fa to replace HCFC-141b (GWP value 220) entirely, the total aggregate demand of HFC-245fa is 31,870 tons in 2015, and increases to 77,700 tons in 2020.

Following Figure shows the demand forecasting of the HFCs in China, without taking any control policy.

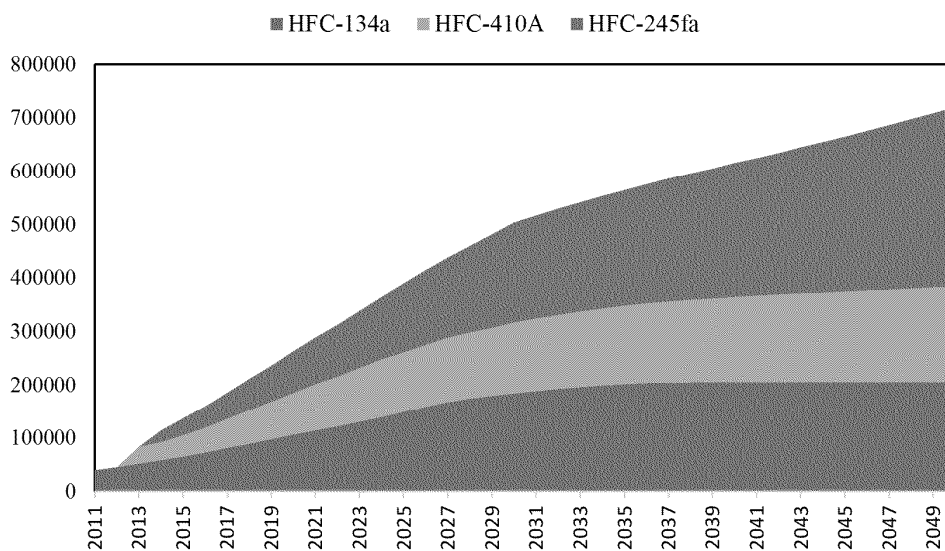


Fig. 21 Demand forecast of HFCs in China by baseline scenario

HFC-23

As a by-product during the manufacture of HCFC -22, HFC-23 emission could reach 30178 tons in BAU scenario which equivalent to 447 MtCO₂eq by 2050.

Total HFCs emissions

Under the BAU scenario, the prediction of HFCs emissions in China is shown in Figure 20. The emission characteristics of different sectors and different consumption are taken into consideration. According to the forecast, if there is no measure for controlling HFC emission, the total emission of HFCs could reach to 360 million tons CO₂eq in 2015, and increase to 500 million tons CO₂eq in 2020, even more than 1000 million tons CO₂eq in 2050.

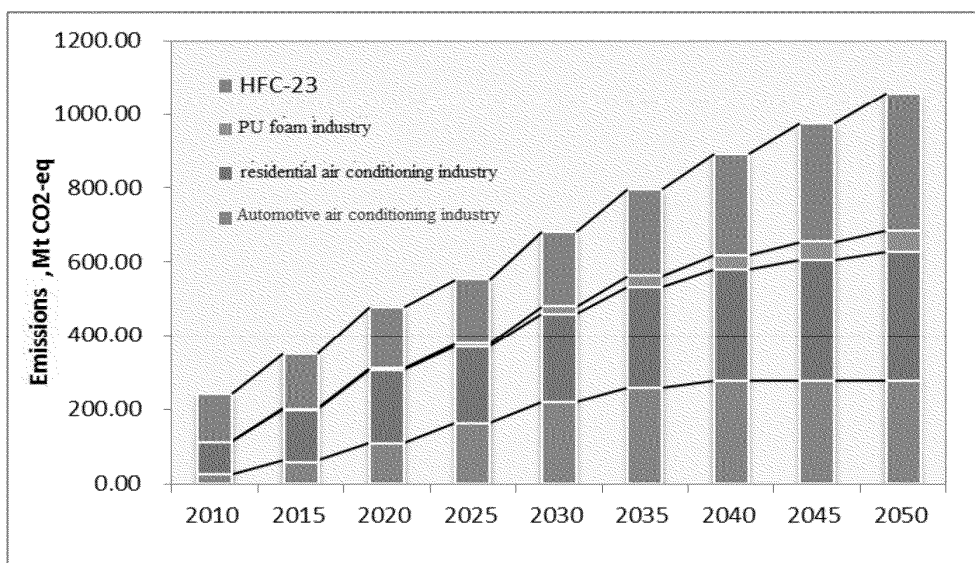


Fig. 22 The predicted emissions under the BAU scenario

0.6.1.2 The mitigation potentials of HFCs emissions

The maximum mitigation potential of HFCs in China could be taken in three aspects: (1) Proper incineration method could reduce the emissions of HFC-23; and technical optimization could be reduced the generation of HFC -23 during chemical process; (2) and to replace the use of HFC -134a in MAC sector gradually; (3) Avoid using HFCs or lower GWP HFCs for HCFC alternatives.

HFO-1234yf and CO₂ could be used as alternatives to replace the usage of HFC-134a in the MAC sector. And the prediction is showed that about 47 million tons CO₂eq emission could be reduced in 2020.

Based on the Montreal Protocol, HCFC-22 used in RAC sector, will be phased out from 2013. And HFC-410A will be used to alternative HCFC-22, however HC-290 and HFC-32 could be used to alternative HFC-410A or replace HCFC-22 in this sector. The prediction is showed that about 34 million tons CO₂eq emission could be reduced in 2020 if HC-290 is used as alternative.

The incremental costs for using alternatives are analyzed for each scenario. For MAC sector, (1) the mainly incremental cost is operating costs for refrigerant if adopt HFO-1234yf as alternative; (2) the operating cost for refrigerant would be saved if adopt HFC-152a or CO₂ as alternative, however, the operating cost for gas would be slightly increased. The costs for mitigation 1 ton of CO₂ emission is about 100 yuan between 2015-2020 under all scenarios, the costs would gradually be decreasing year by year.

It is similar situation for HFC-410A replacement to reducing GHG emission.

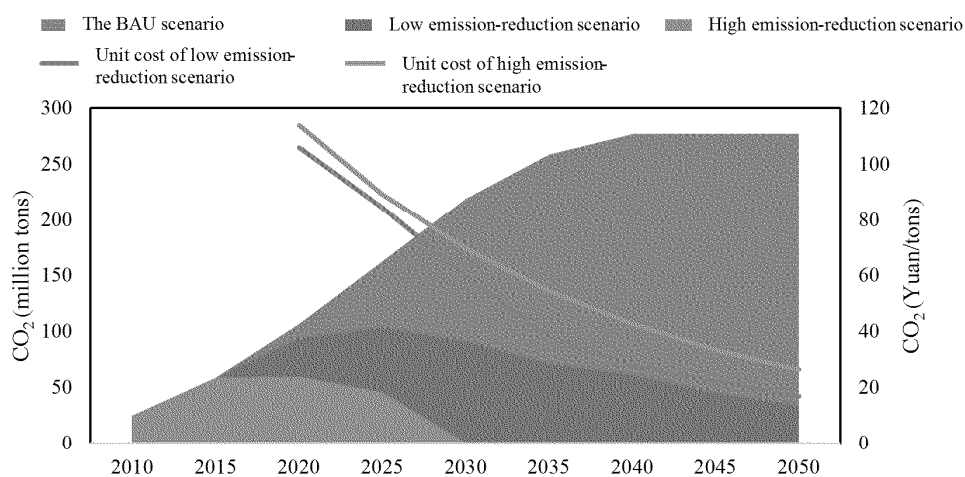


Fig. 23 The HFC-134a emission-reduction potential and cost of the MAC sector

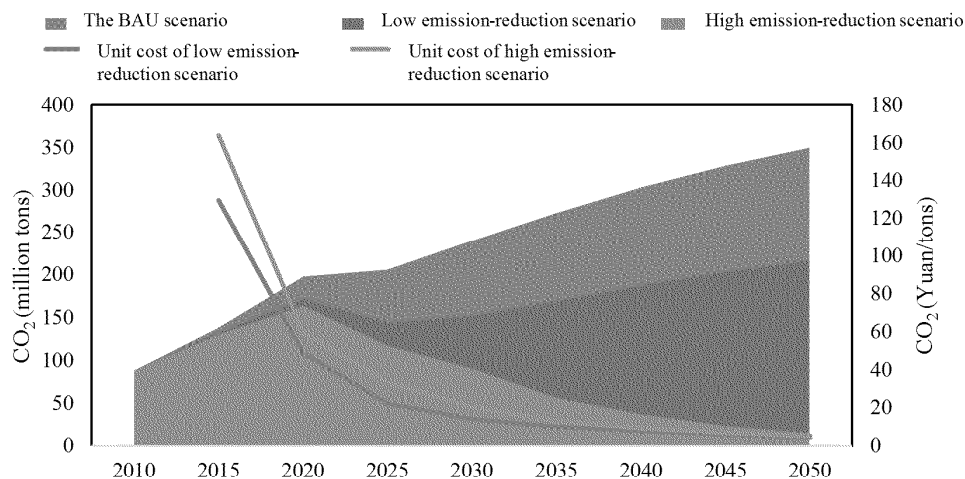


Fig. 24 The HFC-410A emission-reduction potential and cost of the RAC sector

Based on the industry scheme, HCFC-141b used in the PU foam sector, will be phased out from 2013. And HFC-245fa could be used to alternative HCFC-141b, HC could be used to alternative HFC-245fa or HCFC-141b. The prediction is showed that about 3.15 million tons CO₂eq could be reduced by 2020.

It is grand total 45,800 tons HFC-23, amount to 678 million tons CO₂eq that was incinerated by CDM projects from 2006 to 2012 in China. However, the CDM projects for HFC-23 not be decided to keep after 2012 according to current international negotiations. It is assumed that the equipment keep to operate with the fund support from Chinese government or other sources, at least 5,611 tons HFC-23/year, amount to 83 million tons CO₂eq /year, would be reduced.

Based on the HFC-23 CDM projects, the cost for reducing HFC-23 emission should be much lower than that for other HFCs.

In a word, the mitigation potential of HFCs is great in the next decades. The overall national strategy for reducing GHG emissions should include HFCs as one of the priorities.

0.6.2 Opportunities

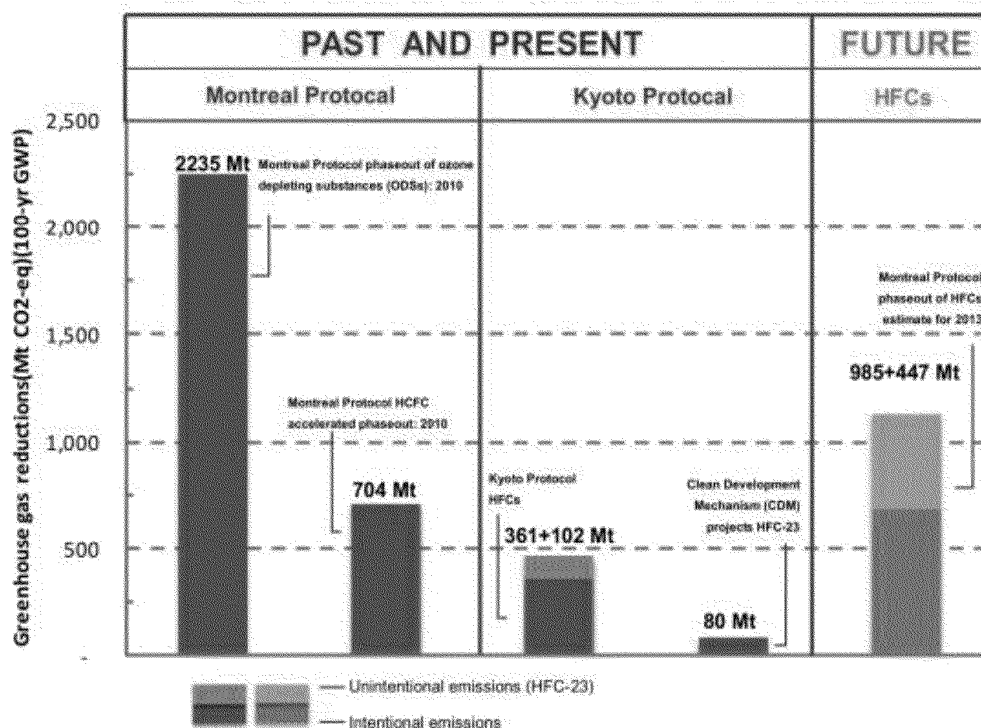


Fig. 25 Climate Protection of the MP and the KP for China

On the one hand, the consumption of HFCs is still at an early stage of development in China, except HFC-134a for MAC. Due to the phaseout of HCFCs and the products needs of economic growth, the consumption of HFCs would be increased rapidly; the growth rate could be even faster than the growth of economic. On the other hand, the international community lay out specific targets for phasing down HFCs consumption to fight against climate change. And the relevant industries in China are facing pressure when they are phasing out HCFCs in the same time. However, there are opportunity and challenge for them to start technology innovation.

0.6.2.1 Better choice for Government to make decisions

The Chinese government takes active actions to fight against climate change and follow the international community. These include change and optimize the economic development pattern, protect public health and ecological environment while developing the economy. The Chinese government lay out specific targets for cutting

40-45% GHG emissions per GDP by 2020. Proposal of this goal, for the relevant industries in China, is another tremendous opportunity to change the development mode and upgrade the industrial technology.

Non-CO₂ gas emission control could play a major role for reducing GHG emission to complete target plan. For example, the cutting of 12% non-CO₂ gas emission completed 32% of the total reduction target plan in Germany. The Chinese government can cut down fluorinated gases preferentially at low cost to achieve the reduction commitment.

0.6.2.2 Better infrastructure for establishment of the international fund mechanism

The United States, Canada and other countries proposed to build clean alliance to control non-CO₂ GHG collectively, like black carbon, methane, HFCs. The three countries of NAFTA also propose that the HFC control should be part of the Montreal Protocol control substances. And it is another tremendous pressure for the developing countries which have to phaseout HCFCs at the same time. On the other hand, it is an opportunity for the developing countries to skip HFCs when select HCFC alternatives. Meanwhile, developing countries lack effective support from the funding mechanisms to cut down the emission of GHG. The Montreal Protocol with multilateral fund mechanism is an effective and successful operation of the mechanism. If the HFC control becomes part of the Montreal Protocol control substances, an effective fund mechanism could be invested in HFC control. That is one of the opportunities to establish an effective fund mechanism to help developing countries to phase down HFCs for protect the climate.

0.6.2.3 A chance to promote energy conservation, technology innovation and emission reduction

HFC application technologies are mainly related with refrigeration, heat energy related technologies. With the control of HFCs, those related technologies need to make innovations and improve the energy efficiency. It is a chance to redesign the

system for better energy efficiency. Thus can promote technological progress, product updates, and promote international cooperation. And it is a good opportunity to protect resources and the ecological environment.

The technologies of the HFC application are more mature and advanced in developed countries. And now, the Chinese enterprises stand in the same starting point with the developed countries; it's a good opportunity to pursue the international advanced level. It is one of the opportunities to use non-HFC to phase out HCFCs directly to avoid secondary selection and use better technologies, which will promote the progress of the alternative technology.

0.6.3 Challenges

As one of countries with the largest GHG emissions and the rapid growth of economies, China faces great pressure and challenge to fight against climate change.

0.6.3.1 High demand of HFCs and its rapid growth in emissions

The consumption of HFCs in China will continue to grow rapidly in the near future years, while HCFCs are being phased out and life span is being promoted. And HFCs are making up an increasing proportion of fluorine-containing GHGs. As mentioned in this report, the HFCs consumption could reach 700,000 tons or 1.0 billion tons of CO₂eq emission in 2050. From a global perspective, HFC-134a as the substance with the highest concentration in atmosphere and the biggest global consumption, Europe, the United States and other developed countries has begun to phase out HFC-134a since 2011. However, the emissions average growth rate of HFC-134a refrigeration in China is higher due to the fast increasing of automobiles. The emissions of HFC-134a could be up to 58 million tons CO₂eq in 2015 and around 100 million tons CO₂eq in 2020. Under the CDM implementation, the emissions of HFC-23, a by-product of HFC-22, have been reduced up to 300 million tons CO₂eq since 2006. If CDM project ended at 2013, about 140 million tons CO₂eq HFC-23 could be directly discharged every year from 2013-2020.

0.6.3.2 Low level of energy saving technology

By the limitation of industrial development level, industrial process and related energy technology products in China consume much energy comparing to that of developed countries. It is still a long way to catch up with the advanced technology to reduce energy consumption. In order to reduce the emissions of HFCs, new technologies are needed urgently, including sealing technology, circulating recovery technology, etc. the energy efficiency levels of related products need to be improved. HFCs application technologies are related with energy technology products, such as refrigeration equipment, insulation products. It much integrated to consider energy efficiency while eliminating the use of HFCs. The energy saving technology is a new requirements and challenges for China.

0.6.3.3 The rapid growth environmental concentration of HFCs

Many studies show that the concentrations of HFCs and HCFCs are increased rapidly. And the average concentrations of HFCs and HCFCs are 1.4-4.8 times than the global background value. The local emissions and emission intensity of HCFCs and HFCs change a lot. And the atmospheric concentration affected by local emissions and meteorological diffusion conditions. The atmospheric concentration spatial variation is more complicated. From the view of spatial distribution, southeast space is higher than the north and west in large scale. And due to the high space urban emissions, its concentration level is higher than the suburbs in small scale. The results of the study show that: from the time series, the atmospheric concentrations of HCFCs and HFCs are growing rapidly, especially the concentrations of HFCs, which is worth attention.

0.6.3.4 Pressure from international society

Nowadays, China's consumption and production of HFCs has already taken a substantial proportion in the whole world. The Clean Alliance advocated by American, Canada and other countries put huge pressure on China, India and many developing countries. What's more, the proposals of adding HFCs controlling measures into the Montreal Protocol are making phasing-out HCFC much more difficult for China.

0.6.3.5 Limitation of alternatives for HFCs

Phasing-out fluorinated GHGs (HCFCs and HFCs) is a difficult task to China. Since fluorinated GHGs are quite environmental friendly and safe (basically nonpoisonous odorless and nonflammable), they can never be easy to find the similar alternatives which are environmental friendly and safe, also are match technical feasibility, efficacy, availability; and accessibility. Due to the above reasons, a Limitation of alternatives is the main obstacle in the way of controlling fluorinated GHGs to China. Related scientific research for the replacing substance and techniques haven't launched fully in China.

0.6.3.6 Insufficient investment for researching on mitigation techniques

As with the rapid economic development, Chinese enterprises are suffering from a huge risk of limited investment on researching along with the weakness on this aspect. Faced with the fierce competition in the international market, it is a great challenge for Chinese enterprises to optimize the energy efficiency, seek out the appropriate replacement and keep their market share under the plight caused by environment trade barrier.

0.6.4 Social and economic impact for mitigation

0.6.4.1 Impact on related sectors

Mobile sector plays a crucial role in economy development for a nation, in which MAC takes just a part in the terms of both importance and cost. The emission reduction cost calculated based on the current replacement technology is 100 yuan/ton CO₂eq, which means if a manufacturer uses HFO-1234yf as the replacement, the cost of each new mobile would be increased 500 yuan due to using alternative refrigerant agent, and using HFC-152a or other replacement would be increased the cost for other process. The elevated cost is not noticeable for a mobile priced at several hundred thousand. China has already become the biggest mobile market for both manufacturing and consuming. Therefore it can be anticipated that along with technique development and cost declining, cost for emission reduction would

decrease year by year. The advantage of using the available technique in the market is relatively small social impact. What's more, regarding the requirement for training servicing workers is not high, establishing new regulations for MAC wouldn't increase supervising cost substantially.

As to RAC, there are limited alternatives for HFC-410A; the available one is HC cost about 3yuan/ton CO₂eq for mitigation. However, it should be paid attention that HC is quite flammable and explosive which bring about risk to manufacture, installation and application. Once accident occurs, it would absolutely cause catastrophe, therefore using HC technique put the enterprises and users under risk. For the sake of safety, plenty of new technique standards and relative training are necessary, which elevated the social and management cost. Further more, the application of HC products may be limited due to the charge amount of HC. However, on the other side, since adopting alternative technique raise demand for management, it could be a good chance to promote enterprises' technical and management level.

0.6.4.2 Environmental influence

The most obvious environmental benefit of reducing HFCs emission is protecting the climate. Although most HFCs are nonpoisonous agents with limited environmental impact, some other chemicals are consumed in the process of manufacturing HFCs, such as H₂SO₄, and producing these chemicals could be contaminating environment. In the sectors that could introduce HC as replacement, such as MAC and PU foam, adopting R-290 and pentamethylene as blowing agent reduced environmental impact to some extent.

As to the indirectly environmental impact, since electricity generation sector is a classical contaminative sector, and using alternatives could improve agents' energy efficiency, replacing measurement decreasing the emission of VOCs, SO₂, NO_x and particles.

0.6.4.3 Demonstrating China's devotion to global environment issues (international treaty fulfillment)

Controlling GHG emission and relieving climate change have already become a hot-spot issue in the international society. As the country contribute substantial CO₂ emission, China is facing great pressure for saving resource and protecting the climate. Even though there is no provision concerning China's obligation reducing GHG emission in Kyoto Protocol, China is in faced of increasingly pressure as with the fast economy development. Under such condition, establishing measurements to control HFCs emission initiatively and reaching the goal of declining greenhouse emission to 40-45% for each unit GDP would definitely demonstrate China's highlight attention toward global environmental issues, contribution to fulfillment of international treaty and manifest China's responsible powerful nation image.

0.6.5 Possible actions on HFCs emission reduction

Based on China's economy development requirement, to regulate practically and properly, act timely and contribute to GHG emission reduction and environment protection is possible. In the process of fulfilling Montreal Protocol, the impact caused by China's HCFCs emission on ozone depletion and climate change would last for a while, however HFCs emitting will affect the climate change more and more adversely and noticeably. Qualification and quantification on these impacts will also focus attention from various fields including scientists, government and the public. Government and industry associations should identify crucial chemicals (HFCs), sector and region, as well as establishing relative regulations and measurements in order to control HCFCs and HFCs emitted from China.

0.6.5.1 Setting feasible goals and developing crucial chemical management

In fact, HFCs consumption in China has just been started, in addition to the fact phaseout of HCFCs would inevitably introduce HFCs, therefore production and consumption of HFCs in the future will be increased constantly, so emission reduction

potential for the year of 2020 is quite limited due to early stage. However, HFC-23 emission reduction potential is higher.

This research mainly analyzes two main manufacture sectors, HFC-134a consumption in mobile air-conditioner sector and HFC-410A consumption in residential air-conditioner sector. Based on the scenarios set by this report and experiences from developed countries, controlling management regarding HFC-134a consumption in MAC can be launched around 2020 (Europe Union constrict HFC-134a in MAC from 2011), which could be 10 years later than EU timetable.

As to control HFC-410A consumption in RAC sector, measurements should be taken to avoid HFC-410A consumption, especially for small size residential air-conditioners. China should make timetables under the condition of available techniques and standards, then it is anticipated HFC-410A consumption and emission can be lowered after 2015, which means air-conditioner for small rooms can introduce R-290 to replace part of HFC-410A, but the whole consumption of HFC-410A in air-conditioner sector will increase gradually.

For both of MAC sector and RAC sector, HFCs consumption for the future 5 years will increase noticeably. Even if proper alternatives and their infrastructures can be available after 5 years, due to the need for the time to spread, total consumption and emission in 2020 could be lifted. It is calculated that the emission reduction potential for 2020 depends on alternatives to a crucial extent, but replacement development trend is not clear now. The predicted emission reduction potential for 2020 will rely on developing situations of alternative techniques. By fulfilling the international treaty, the concrete emission reduction measurements could be taken in the following two aspects: firstly, decreasing consumption and leakage by choosing replacement and improve technique, secondly, reducing the in tank emission by recycling wasted products. However on the terms of choosing specific approaches, scientists and government should develop assessments for regulations and techniques under the environmental, social and economic criteria.

0.6.5.2 Assessing HFC impact on climate change

Assessing HFC impact on climate change is a crucial task for policy making. On one hand, it should be understand current emission condition and situation of both sectors and specific origins. That will benefit in favor of emission calculation, making inventory and future management. On the other hand, It should be recognize its trend and assess its contribution to global warming from scientific point of view, as well as identifying changes and influences of fluorinated GHGs, relatively to CO₂, CH₄ and N₂O. The above measurements will set solid foundation for future fluorinated GHGs management.

0.6.5.3 Establish emissions control financial system , promote alternative and emission reduction technology

In the process of phaseout HCFCs, on the one hand, it should be chosen HFCs alternatives carefully; on the other hand, measurements can be taken to improve the technology and strengthen recycling segment. And the final goal is gradually to reduce fluorine GHGs (HCFCs and HFCs) consumption and emission.

The main related consumption industry for HFCs contains two major sectors, one is relatively energy intensive sectors, refrigeration and air conditioning sector; the other one is insulation energy -saving foam plank, which means fluorine GHG products is also closely related with climate change. Therefore, promoting technological progress in these areas, active investment and development of the technology of energy conservation and environmental protection products is very important; that is a win -win situation . Research and development for proper alternative for China is very important, which calls for innovation. And combined with the international society's support, such as multilateral fund and the global environment facility, establishing incentive mechanism in this field is in favor of fluorinated GHG control and elimination.

0.6.5.4 Improve laws and regulations related to emission control system

It should be to formulate related policies and measures to limit and reduce fluorinated GHG emissions based on China's existing laws and regulations. With reference of foreign experience, command control policy is the fundamental way to eliminating fluorinated GHG, and as the guarantee to realize command control policy goal, it is necessary to establish a mechanism led by government with enterprises as the main body as well as involvement of industry and public. What's more, economic effective technical and financial support should also be in place. Besides, reducing unnecessary fluorinated GHG demand through the policies and regulations, improving relevant product sealing, and recycling utilization can also be the effective control measures.

0.6.5.5 Define HFCs management organizations and system

The existing ozone depletion substance consumption control system is the most suitable for managing HFCs, which can be reflected in the following four aspects: (1) CFCs, HCFCs and HFCs are products in the fluorine chemical industry, most of the CFCs and HCFCs production and consumption enterprises, are also the production and consumption enterprises for HFCs, which means the management organization is not changed (preliminary estimates 80% of the enterprises participated ODS phasing-out previously). (2) Consumption application industry and products for HFCs are basically same with CFCs and HCFCs. What's more, the relevant technology standard management institutions and professional experts are also similar. (3) CFCs, HCFCs and HFCs all are chemicals that caused global environment problems which is environmental protection departments' responsibilities. (4) The existing ozone layer material policy management system has gone through more than 20 years of development, establishing the involvement mechanism including department, associations, enterprises, specialists, public and the international society, with a crew of talents, which lay solid foundation and enable China to launch HFCs management during a short period time. Therefore it is a quite urgent issue to define the existing ODS controlling system's obligation and status in the progress of controlling HFCs, which is in favor of keeping China's leading status and protecting the state's interests

in international negotiation and establish relevant strategy and policy, and for the most crucial part, carrying out fluorinate GHG emissions controlling measurement smoothly.

To: Maranion, Bella[Maranion.Bella@epa.gov]
Cc: Newberg, Cindy[Newberg.Cindy@epa.gov]; Godwin, Dave[Godwin.Dave@epa.gov]
From: Sheppard, Margaret
Sent: Mon 11/18/2013 8:26:47 PM
Subject: RE: DRAFT SNAP Status Change Rule
[DRAFT SNAP Status 111813-dsg mas.docx](#)
[List of questions on status change rule 11-15-13.docx](#)

Bella,

Here's the revised version, plus the list of questions based on some of the issues or questions not yet resolved.

Some of the bigger questions I want to highlight:

Ex. 5 - Deliberative Process

Also, the rule language needs to include dates, throughout.

Now I'm going back to sleep...

Margaret

From: Maranion, Bella
Sent: Friday, November 15, 2013 10:26 AM
To: Sheppard, Margaret
Cc: Newberg, Cindy; Godwin, Dave
Subject: FW: DRAFT SNAP Status Change Rule

Margaret,

Were you planning any further review or revisions to this draft from Dave? If not, I was going to organize a group meeting next week, as Dave suggests, to go through this draft one more time to decide what changes to accept and what to leave in as edits, comments for the version that will go to OGC.

Thanks,

Bella

From: Godwin, Dave
Sent: Tuesday, November 12, 2013 1:37 PM
To: Newberg, Cindy; Sheppard, Margaret; Maranion, Bella; Landolfi, Robert
Cc: VonDemHagen, Rebecca; Fiffer, Melissa; Arling, Jeremy; Rim, Elisa
Subject: RE: DRAFT SNAP Status Change Rule

Here's the latest draft with a few more revisions from me. Redline/strikeout is getting fairly extensive – maybe after this round Cindy or us as a group can go through and decide what to accept and what to leave in as potential edits, comments for further discussion, etc.

Also, my first thoughts on the Qs below.

From: Newberg, Cindy
Sent: Monday, November 04, 2013 9:24 AM
To: Sheppard, Margaret; Maranion, Bella; Landolfi, Robert
Cc: VonDemHagen, Rebecca; Godwin, Dave; Fiffer, Melissa; Arling, Jeremy; Rim, Elisa
Subject: RE: DRAFT SNAP Status Change Rule

Wow – it is obvious how hard folks have been working given how far along this draft is and how thoughtful the comments are. I went through the preamble and my comments are included. There are a few issues we need to discuss but generally, I think we are on track to get a clean version put together to go to OGC.

Things to discuss:

Ex. 5 - Deliberative Process

Ex. 5 - Deliberative Process

Lastly, briefings and intra-agency discussions:

- 1) We need a discussion with OTAQ before we share paper (Rebecca – let's disc schedules)
- 2) We will need several OGC discussions
- 3) We'll need to develop a summary doc.
- 4) we will need to brief Janet early to mid-December Thanksgiving so we'll need a pre-brief ahead of that for Sarah

Perhaps we can all sit down later this week (or most of us).

Cindy Newberg

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From: Sheppard, Margaret
Sent: Thursday, October 24, 2013 4:20 PM
To: Maranion, Bella; Landolfi, Robert; Cindy Axinn Newberg; Newberg, Cindy
Cc: VonDemHagen, Rebecca; Godwin, Dave; Fiffer, Melissa
Subject: RE: DRAFT SNAP Status Change Rule

Bella and Cindy,

Here is the latest draft of the status change rule. Rob, thanks for the edits!

Margaret

From: Maranion, Bella
Sent: Thursday, October 24, 2013 12:39 PM
To: Sheppard, Margaret; Landolfi, Robert
Subject: Re: DRAFT SNAP Status Change Rule

Thanks, Margaret. Once Rob replaces science section, then please send back to me and Cindy asap. We can review on our return trip.

Thanks a lot!
Bella

From: Sheppard, Margaret
Sent: Thursday, October 24, 2013 9:32:13 AM
To: Maranion, Bella; Landolfi, Robert
Subject: RE: DRAFT SNAP Status Change Rule

Rob and Bella,

Here's an updated version of the rule that includes draft rule language, FR template at the beginning, and EO template at the end.

Rob, if you haven't already finished your work on the science section, please add to this document instead.

Margaret

From: Maranion, Bella
Sent: Thursday, October 17, 2013 10:00 AM
To: Godwin, Dave; Sheppard, Margaret; Landolfi, Robert
Cc: VonDemHagen, Rebecca
Subject: FW: DRAFT SNAP Status Change Rule

Hi guys and welcome back!

Thanks to Dave for getting to this before the shutdown!

Margaret – I have you as holding the pen on this draft now?

Rob – Because I start traveling to Bangkok tomorrow and will be out of the office next week, could I ask you to perhaps incorporate your revised science section into Margaret's draft? That would be very helpful in order to get something to Cindy for review soon as she's requested.

Dave – with regard to your other issues, perhaps you could discuss these with Margaret and Rebecca to keep these moving? I don't know if these need to be discussed with Cindy first which will not happen until we return from travel the week of Oct. 28th.

Thanks,

Bella

From: Godwin, Dave
Sent: Friday, September 27, 2013 10:42 PM
To: Maranion, Bella; Landolfi, Robert
Cc: Sheppard, Margaret; Newberg, Cindy
Subject: RE: DRAFT SNAP Status Change Rule

Thanks, I'm relinquishing the pen! Added several pages mainly in the commercial refrigeration section reflecting what I think we decided upon last week.

I know Rob has been reviewing in parallel but hopefully our comments don't overlap (I don't think I added any new edits or comments to the science section).

Two main points that I think we still need to discuss

Ex. 5 - Deliberative Process

From: Maranion, Bella

Sent: Tuesday, September 24, 2013 12:50 PM
To: Godwin, Dave; Landolfi, Robert
Cc: Sheppard, Margaret; Newberg, Cindy
Subject: FW: DRAFT SNAP Status Change Rule

Dave – please find the last version of the marked up draft rule which I sent out last week before our meeting, so doesn't yet reflect that discussion. So I have you holding the pen on the draft version for now.

Margaret – you can take a look but maybe wait to get Dave's changes to add yours so we can keep version control.

Rob – FYI the science discussion that needs work starts at the bottom of page 13 through page 15. I thought having the draft rule context would be helpful to your work on this section. I suggest that you re-draft this section on a separate track/document and we can drop into the next revised draft of this rule at some point, just to help with version control.

Thanks,

Bella

From: Maranion, Bella
Sent: Thursday, September 19, 2013 9:42 AM
To: Newberg, Cindy
Cc: Godwin, Dave; Sheppard, Margaret
Subject: DRAFT SNAP Status Change Rule

Cindy,

Please find attached the latest draft of the Status Change rule with Dave's and Margaret's edits and comments. This will need your review and further discussion. I thought that at our meeting today, we could highlight and discuss some of the key questions/issues in the sectors, as well as overall status.

For the overall discussion, I am also attaching the update that Dave presented at T6 last week, plus the rules timeline table that we've reviewed previously in T6.

Thanks,

Bella

To: Newberg, Cindy[Newberg.Cindy@epa.gov]
From: Cindy Newberg
Sent: Fri 6/14/2013 3:37:38 PM
Subject: updated rule
[delist framing-June 15.doc](#)

oy

To: Godwin, Dave[Godwin.Dave@epa.gov]; Sheppard, Margaret[Sheppard.Margaret@epa.gov]
From: Newberg, Cindy
Sent: Thur 8/1/2013 11:36:47 AM
Subject: very drafty delisting rule
[delist framing-July 31.doc](#)

Dave/Margaret –

This is a rough start at a proposal. There's lots of gaps and placeholders. However, before going much further, I thought it would be helpful to see if you think this is on the right track and get some early input. If you have time within the next week, I would appreciate your thoughts.

-Cindy

To: Maranion, Bella[Maranion.Bella@epa.gov]
From: Newberg, Cindy
Sent: Thur 4/18/2013 12:48:22 PM
Subject: next draft
[delist framing-rev2.docx](#)

Okay, see what you think. Still rough but maybe all the general background is there – sorta.

Cindy Newberg, Chief

Alternatives and Emissions Reduction Branch

Office of Atmospheric Programs

Office of Air and Radiation

U.S. Environmental Protection Agency

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To: Maranion, Bella[Maranion.Bella@epa.gov]
From: Newberg, Cindy
Sent: Wed 4/17/2013 10:43:01 PM
Subject: probably not worth reading yet
[delist framing-rev1.docx](#)

Just so you have my latest version – but this is probably not ready to really review

Cindy Newberg, Chief

Alternatives and Emissions Reduction Branch

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Office of Air and Radiation

U.S. Environmental Protection Agency

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To: Maranion, Bella[Maranion.Bella@epa.gov]
From: Newberg, Cindy
Sent: Tue 4/16/2013 7:55:56 PM
Subject: very rough draft
[delist framing.docx](#)

Cindy Newberg, Chief

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To: Paul Horwitz[Horwitz.Paul@epamail.epa.gov]
From: Newberg, Cindy
Sent: Fri 3/1/2013 7:12:54 PM
Subject: 2009 finals and a bit more
[State EPA briefing N2O as ODS ARR final 19082009.ppt](#)
[123.pdf](#)
[Desk Statement on Nitrous Oxide Article in Science.doc](#)
[fact sheet about N2O ARR 8 18 09.doc](#)
[R40874.pdf](#)
[Ravishankara-08-28-09.pdf](#)
[ravishankaraSOM.pdf](#)
[N2O.docx](#)

Attached are the 2009 docs. The only one that was EPA's is the desk statement. Also, the N2O.docx document is from the position. I'll find the bit we sent to Dan at MOP-25 and send that separately. It's just a few sentences.

Cindy Newberg, Chief

Alternatives and Emissions Reduction Branch

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III. How does the SNAP program work? [SECTION III IS STANDARD, THE DISCUSSION IS IN IV STARTING ON P6. THIS SECTION PROVIDES CONTEXT]

A. What are the statutory requirements and authority for the SNAP program?

Section 612 of the Clean Air Act (CAA) requires U.S. Environmental Protection Agency (EPA) to develop a program for evaluating alternatives to ozone-depleting substances. This program is known as the Significant New Alternatives Policy (SNAP) program. The major provisions of section 612 are:

1. Rulemaking

Section 612(c) requires EPA to promulgate rules making it unlawful to replace any class I (e.g., chlorofluorocarbon, halon, carbon tetrachloride, methyl chloroform, methyl bromide, and hydrobromofluorocarbon) or class II (e.g., hydrochlorofluorocarbon) substance with any substitute that the Administrator determines may present adverse effects to human health or the environment where the Administrator has identified an alternative that (1) reduces the overall risk to human health and the environment, and (2) is currently or potentially available.

2. Listing of Unacceptable/Acceptable Substitutes

Section 612(c) requires EPA to publish a list of the substitutes unacceptable for specific uses and to publish a corresponding list of acceptable alternatives for specific uses. The list of acceptable substitutes is found at <http://www.epa.gov/ozone/snap/lists/index.html> and the lists of “unacceptable,” “acceptable subject to use conditions,” and “acceptable subject to narrowed use limits” substitutes are found in the appendices to 40 CFR part 82 subpart G.

3. Petition Process

Section 612(d) grants the right to any person to petition EPA to add a substance to, or

delete a substance from the lists published in accordance with section 612(c). The Agency has 90 days to grant or deny a petition. Where the Agency grants the petition, EPA must publish the revised lists within an additional six months.

4. 90-day Notification

Section 612(e) directs EPA to require any person who produces a chemical substitute for a class I substance to notify the Agency not less than 90 days before new or existing chemicals are introduced into interstate commerce for significant new uses as substitutes for a class I substance. The producer must also provide the Agency with the producer's unpublished health and safety studies on such substitutes.

5. Outreach

Section 612(b)(1) states that the Administrator shall seek to maximize the use of federal research facilities and resources to assist users of class I and II substances in identifying and developing alternatives to the use of such substances in key commercial applications.

6. Clearinghouse

Section 612(b)(4) requires the Agency to set up a public clearinghouse of alternative chemicals, product substitutes, and alternative manufacturing processes that are available for products and manufacturing processes which use class I and II substances.

B. What are EPA's regulations implementing section 612?

On March 18, 1994, EPA published the original rulemaking (59 FR 13044) which established the process for administering the SNAP program and issued EPA's first lists identifying acceptable and unacceptable substitutes in the major industrial use sectors (40 CFR

part 82, subpart G). These sectors include: refrigeration and air conditioning; foam blowing; solvents cleaning; fire suppression and explosion protection; sterilants; aerosols; adhesives, coatings and inks; and tobacco expansion. These sectors comprise the principal industrial sectors that historically consumed the largest volumes of ozone-depleting substances (ODS).

Section 612 of the CAA requires EPA to list as acceptable those substitutes that do not present a significantly greater risk to human health and the environment as compared with other substitutes that are currently or potentially available.

C. How do the regulations for the SNAP program work?

Under the SNAP regulations, anyone who produces a substitute to replace a class I or II ODS in one of the eight major industrial use sectors must provide notice to the Agency, including health and safety information on the substitute at least 90 days before introducing it into interstate commerce for significant new use as an alternative. 40 CFR 82.176(a). This requirement applies to the person planning to introduce the substitute into interstate commerce,¹ typically chemical manufacturers, but may also include importers, formulators, equipment manufacturers, or end-users² when they are responsible for introducing a substitute into commerce. The 90-day SNAP review process begins once EPA receives the submission and determines that the submission includes complete and adequate data. 40 CFR 82.180(a). The CAA and the SNAP regulations, 40 CFR 82.174(a), prohibit use of a substitute earlier than 90-days after notice has been provided to the Agency.

¹ As defined at 40 CFR 82.104 “interstate commerce” means the distribution or transportation of any product between one state, territory, possession or the District of Columbia, and another state, territory, possession or the District of Columbia, or the sale, use or manufacture of any product in more than one state, territory, possession or District of Columbia. The entry points for which a product is introduced into interstate commerce are the release of a product from the facility in which the product was manufactured, the entry into a warehouse from which the domestic manufacturer releases the product for sale or distribution, and at the site of United States Customs clearance.

² As defined at 40 CFR 82.172 “end-use” means processes or classes of specific applications within major industrial sectors where a substitute is used to replace an ozone-depleting substance.

The Agency has identified four possible decision categories for substitutes: acceptable; acceptable subject to use conditions; acceptable subject to narrowed use limits; and unacceptable.³ 40 CFR 82.180(b). Use conditions and narrowed use limits are both considered “use restrictions” and are explained below. Substitutes that are deemed acceptable with no use restrictions (no use conditions or narrowed use limits) can be used for all applications within the relevant end-uses within the sector. Substitutes that are acceptable subject to use restrictions may be used only in accordance with those restrictions.

After reviewing a substitute, the Agency may determine that a substitute is acceptable only if certain conditions in the way that the substitute is used are met to minimize risks to human health and the environment. EPA describes such substitutes as “acceptable subject to use conditions.” Entities that use these substitutes without meeting the associated use conditions are in violation of section 612 of the Clean Air Act and EPA’s SNAP regulations. 40 CF 82.174(c).

For some substitutes, the Agency may permit a narrow range of use within an end-use or sector. For example, the Agency may limit the use of a substitute to certain end-uses or specific applications within an industry sector. The Agency requires a user of a narrowed use substitute to demonstrate that no other acceptable substitutes are available for their specific application by conducting comprehensive studies. EPA describes these substitutes as “acceptable subject to narrowed use limits.” A person using a substitute that is acceptable subject to narrowed use limits in applications and end-uses that are not consistent with the narrowed use limit, are using these substitutes in an unacceptable manner and are in violation of section 612 of the CAA and EPA’s SNAP regulations. 40 CFR 82.174(c).

The Agency publishes its SNAP program decisions in the *Federal Register* (FR). EPA

³ The SNAP regulations also include “pending,” referring to submissions for which EPA has not reached a determination, under this provision.

publishes decisions concerning substitutes that are deemed acceptable subject to use restrictions (use conditions and/or narrowed use limits), or for substitutes deemed unacceptable, as proposed rulemakings to allow the public opportunity to comment, before publishing final decisions.

In contrast, EPA publishes substitutes that are deemed acceptable with no restrictions in “notices of acceptability,” rather than as proposed and final rules. As described in the preamble to the rule initially implementing the SNAP program (59 FR 13044; March 18, 1994)), EPA does not believe that rulemaking procedures are necessary to list alternatives that are acceptable without restrictions because such listings neither impose any sanction nor prevent anyone from using a substitute.

Many SNAP listings include “comments” or “further information” to provide additional information on substitutes. Since this additional information is not part of the regulatory decision, these statements are not binding for use of the substitute under the SNAP program. However, regulatory requirements so listed are binding under other regulatory programs (e.g., worker protection regulations promulgated by the U.S. Occupational Safety and Health Administration (OSHA)). The “further information” classification does not necessarily include all other legal obligations pertaining to the use of the substitute. While the items listed are not legally binding under the SNAP program, EPA encourages users of substitutes to apply all statements in the “further information” column in their use of these substitutes. In many instances, the information simply refers to sound operating practices that have already been identified in existing industry and/or building-codes or standards. Thus, many of the statements, if adopted, would not require the affected user to make significant changes in existing operating practices.

D. How are SNAP determinations updated?

Three mechanisms exist for revising or expanding the list of SNAP determinations. The first two mechanisms are described in Section A: petition process and 90-day notification. First, under section 612(d), the Agency will review and either grant or deny petitions to add or delete substances from the SNAP list of acceptable or unacceptable alternatives. The second means of revising or expanding the list of SNAP determinations is through the notifications which must be submitted to EPA 90 days before introduction of a substitute into interstate commerce for significant new use as an alternative to a class I or class II substance. These 90-day notifications are required by section 612(e) of the CAA for producers of alternatives to class I substances for new uses and by EPA regulations issued under sections 114 and 301 of the Act to implement section 612(c) in all other cases.

Finally, the Agency believes that section 612 authorizes it to initiate changes to the SNAP determinations independent of any petitions or notifications received. These amendments can be based on new data on either additional substitutes or on characteristics of substitutes previously reviewed.

E. Where can I get additional information about the SNAP program?

For copies of the comprehensive SNAP lists of substitutes or additional information on SNAP, refer to EPA's web site at www.epa.gov/ozone/snap/index.html. For more information on the Agency's process for administering the SNAP program or criteria for evaluation of substitutes, refer to the SNAP final rulemaking published March 18, 1994 (59 FR 13044), codified at 40 CFR part 82, subpart G. A complete chronology of SNAP decisions and the appropriate citations are found at <http://www.epa.gov/ozone/snap/chron.html>.

IV. When would EPA modify a Determination?

EPA is proposing to modify previous determinations that listed certain alternatives as acceptable or acceptable subject to use conditions to list these alternatives as unacceptable. As described in this document and elsewhere, including the original SNAP rulemaking published in the Federal Register on March 18, 1994 (59 FR 13044), the SNAP program evaluates substitutes within a comparative risk framework. The comparisons are to both the ozone-depleting substances being phased out under the *Montreal Protocol on Substances that Deplete the Ozone Layer* and the CAA and other available or potentially available alternatives for the same end uses. The environmental and health risk factors that the SNAP program considers include ozone depletion potential, flammability, toxicity, occupational and consumer health and safety, as well as contributions to global warming and other environmental factors. Environmental and human health exposures can vary significantly depending on the particular application of a substitute – and over time the information applicable to a substitute can change. This approach does not imply fundamental tradeoffs with respect to different types of risk, either to the environment or to human health. It recognizes also that the same substances could be used in very different applications with very different environmental and human health exposures. For example, a substance used as a propellant in aerosols may also be used as foam blowing agent and as a refrigerant.

EPA recognizes that during the nearly two decade history of the SNAP program, new information has emerged. To the extent possible, EPA considers new information and improved understanding of the risk factors for the environment and human health. EPA has previously revised determinations to modify a listing from acceptable or acceptable with use conditions to unacceptable based on a variety of factors including information made available to EPA after a listing was issued. For example, on January 26, 1999 EPA lists as unacceptable for all

refrigeration and air-conditioning end-uses the refrigerant blend known by the trade name MT-31. This refrigerant blend was previously listed as an acceptable substitute in various end-uses within the refrigerant and air-conditioning sector. After listing MT-31 as acceptable, EPA became aware of toxicity data concerning one of the chemicals contained in the MT-31 blend that present significant concerns about risks to human health that may arise as a result of the use of this chemical, either alone or in a blend. Therefore, EPA removed MT-31 from the list of acceptable substitutes, and listed MT-31 as unacceptable in all refrigeration and air-conditioning end uses (1999 64 FR 3861). Another example of EPA taking such action occurred in 2007 when EPA modified previous determinations of acceptability and determined that HCFC-22 and HCFC-142b were unacceptable for use in the foam sector.

It is important to understand that class II substances, or HCFCs, which are ozone-depleting and subject to a global phaseout, were also acceptable substitutes to class I ODS and listed in many cases as acceptable in initial actions under the SNAP program because they were safer alternatives to the class I ODS. HCFCs offered a path forward for some sectors and end uses at a time where alternatives were far more limited. At the same time, in 1994 the Nonessential Products Ban under section 610(d) of the Act banned the sale or distribution or offer of sale or distribution in interstate commerce of HCFCs in aerosols, pressurized dispensers and foam products except for insulating foam products. The relationship between the nonessential products ban and SNAP is important because it meant for example that HCFCs for foam blowing end uses was limited by the ban to only end uses that meet the definition of insulating foams.

A major objective of the SNAP program is to facilitate the transition from ODS by promoting the use of substitutes which present a lower risk to human health and the environment (40 CFR 82.170(a)). A key policy interest in 2007 was to promote the shift from ODSs to alternatives

posing lower overall risk that are currently or potentially available (59 FR 13044). With the 2010 phaseout step fast approaching, EPA modified the previous determinations for specific foam end uses. EPA stated in the final rule that non-ozone depleting alternatives were technically viable and commercially available for nearly all foam applications. EPA stated that continued use of HCFCs would contribute to unnecessary depletion of the ozone layer, and delay the transition to alternatives that pose lower overall risk to health and the environment. Accordingly, EPA:

- (1) Listed HCFC-22 and HCFC-142b as unacceptable substitutes for HCFC-141b in commercial refrigeration, sandwich panels, and slabstock and “other” foam; and
- (2) listed HCFC-22 and HCFC-142b as unacceptable substitutes for CFCs in all foam end uses.

In that final rule, EPA allowed for grandfathering which varied based on the specific end use and chemical combination. EPA allowed existing users to continue use for a limited time to ensure that they could adjust their manufacturing processes to safely accommodate the use of other alternatives.

As the examples above illustrate, EPA has previously revised determinations to modify a listing from acceptable or acceptable with use conditions to unacceptable based on a variety of factors including new information and improved understanding on either additional substitutes or on characteristics of substitutes previously reviewed.

On December 7, 2009, the Administrator signed two distinct findings regarding greenhouse gases under section 202(a) of the Clean Air Act:

- Endangerment Finding:** The Administrator finds that the current and projected concentrations of the six key well-mixed greenhouse gases — carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF₆) — in the atmosphere threaten the public health and welfare of current and future generations.
- Cause or Contribute Finding:** The Administrator finds that the combined emissions of these well-mixed greenhouse gases from new motor vehicles and new motor vehicle engines contribute to the greenhouse gas pollution which threatens public health and welfare.

What is relevant background for this action is the scientific and technical information summarized to support the Endangerment and Cause or Contribute Findings for Greenhouse Gases under the Clean Air Act can be found at:

http://www.epa.gov/climatechange/Downloads/endangerment/Endangerment_TSD.pdf

The Earth's average temperature has risen by 1.4°F over the past century, and is projected to rise another 2 to 11.5°F over the next hundred years. Small changes in the average temperature of the planet can translate to large and potentially dangerous shifts in climate and weather. The evidence is clear. Rising global temperatures have been accompanied by changes in weather and climate. Many places have seen changes in rainfall, resulting in more floods, droughts, or intense rain, as well as more frequent and severe heat waves. The planet's oceans and glaciers have also experienced some big changes - oceans are warming and becoming more acidic, ice caps are melting, and sea levels are rising. As these and other changes become more pronounced in the coming decades, they will likely present challenges to our society and our environment. The

buildup of greenhouse gases can change Earth's climate and result in dangerous effects to human health and welfare and to ecosystems. The choices we make today will affect the amount of greenhouse gases we put in the atmosphere in the near future and for years to come. By making choices that reduce greenhouse gas pollution, and preparing for the changes that are already underway, we can reduce risks from climate change.

Like the ODSs they replace, HFCs are potent greenhouse gases. Although their current contribution to climate forcing is about 1% of all other greenhouse gases combined, HFCs have the potential to substantially influence climate in the future. HFCs are rapidly increasing in the atmosphere as a result of their use as ODS replacements. For example, CO₂ equivalent emissions of HFCs (excluding HFC-23) increased by approximately 8% per year from 2004 to 2008. As a consequence, the abundances of HFCs in the atmosphere are also rapidly increasing. For example, HFC-134a, the most abundant HFC, has increased by about 10% per year from 2006 to 2010.

In the future, HFC emissions have the potential to become very large. Under current practices, the consumption of HFCs is projected to exceed by 2050 the peak consumption level of CFCs in the 1980s. This is primarily due to growing demand in emerging economies and increasing populations.

Without intervention, the increase in HFC emissions is projected to offset much of the climate benefit achieved by the earlier reduction in ODS emissions. Annual emissions of HFCs are projected to rise to about 3.5 to 8.8 Gt CO₂eq in 2050 which is comparable to the drop in ODS annual emissions of 8.0 GtCO₂eq between 1988 and 2010.

To appreciate the significance of projected HFC emissions, they would be equivalent to 7 to 19% of the CO₂ emissions in 2050 based on the IPCC's Special Report on Emissions Scenarios

(SRES), and equivalent to 18 to 45% of CO₂ emissions based on the IPCC's 450 ppm CO₂ emissions pathway scenario.

If HFC emissions continue to increase, they are likely to have a noticeable influence on the climate system. By 2050, the buildup of HFCs is projected to increase radiative forcing by up to 0.4 W m⁻² relative to 2000.

This increase may be as much as one-fifth to one-quarter of the expected increase in radiative forcing due to the buildup of CO₂ since 2000, according to the SRES emission scenarios.

Global warming is a factor in the overall evaluation of alternatives under the SNAP program.

EPA is not suggesting a need element in our framework. EPA is recognizing that during the past two decades both the general science on climate change and more specifically the potential contributions of HFCs have become better understood. A summary of some of the recent findings can be found in the docket. A further description of the criteria used by the SNAP program is discussed below.

What Are EPA's Criteria for Evaluating Alternatives Under the SNAP Program?

EPA's evaluation of each alternative in an end-use is based on the following types of information and analyses:

- *Atmospheric effects*- The SNAP program evaluates the potential contributions to both ozone depletion and climate change. The SNAP program considers the ozone depletion potential and the 100-year integrated global warming potential of compounds to assess atmospheric effects.
- *Exposure assessments*- Exposure assessments are used to estimate concentration levels of substitutes to which workers, consumers, the general population, and environmental receptors may be exposed over a determined period of time. These assessments are based

on personal monitoring data or area sampling data if available. Exposure assessments may be conducted for many types of releases including:

- Releases in the workplace and in homes
 - Releases to ambient air and surface water
 - Releases from the management of solid wastes
- *Toxicity data*- Toxicity data is used to assess the possible health and environmental effects for exposure to substitutes. The Occupational Safety and Health Administration (OSHA) or EPA approved wide health based criteria that is available for a substitute such as:
 - Permissible Exposure Limits (PELs for occupational exposure)
 - Inhalation reference concentrations (RfCs for noncarcinogenic effects on the general population)
 - Cancer slope factors (for carcinogenic risk to members of the general population)

If OSHA has not issued a PEL for a compound, EPA also considers Workplace Environmental Exposure Limits set by the American Industrial Hygiene Association or Threshold Limit Values set by the American Conference of Governmental Industrial Hygienists. If limits for occupational exposure or exposure to the general population are not already established, then EPA derives these values following the Agency's peer reviewed guidelines.

Exposure information is combined with toxicity information to explore any basis for concern. Toxicity data is used with existing EPA guidelines to develop health-based criteria for interim use in these risk characterizations.

- *Flammability*- Flammability is examined as a safety concern for workers and consumers.

EPA assesses flammability risk using data on:

- Flash point and flammability limits (e.g. OSHA flammability/ combustibility classifications)
- Data on testing of blends with flammable components
- Test data on flammability in consumer applications conducted by independent laboratories
- Information on flammability risk minimization techniques

- *Other environmental impacts*- The SNAP program also examines other potential environmental impacts such as ecotoxicity and local air quality impacts. A compound that is likely to be discharged to water may be evaluated for impacts on aquatic life. Some substitutes are volatile organic compounds (VOCs). EPA notes whenever a potential substitute is considered a hazardous air pollutant or hazardous waste.

EPA is not proposing to change the overall criteria used in our evaluations of alternatives or our comparative risk approach. EPA continues to view these criteria are appropriate and also is not implying any tradeoffs between these. However, EPA recognizes how we view these criteria should be informed by our overall understanding how best to apply these criteria. We must view these with what we know today about environmental and human health impacts,

and also in the context of what we know about other available and potentially available alternatives. Over time, the range of alternatives has changed.

Since the initial SNAP rule was issued in 1994, EPA has issued 18 rules and 28 notices.

These rules and notices taken together have resulted in expanding the menu of options for all SNAP sectors and end uses. Comparisons today are to a broader range of options – both chemical and non-chemical – than at the inception of the SNAP program. Industry experiences with these alternatives have increased as well during the 20 year history of the program. Again, this varies by sector and by end use.

Similar to in 2007, when EPA determined that previously acceptable HCFCs for foam blowing were no longer acceptable, EPA is today proposing determinations based of alternatives previously listed as acceptable or acceptable subject to use conditions and comparing those alternatives with the range of available or potentially available alternatives.

What Are the Guiding Principles of the SNAP Program?

Evaluate substitutes within a comparative risk framework

The SNAP program evaluates the risk of alternative compounds compared to those of ozone-depleting compounds and available or potentially alternatives. The environmental risk factors that are considered include ozone depletion potential, flammability, toxicity, occupational health and safety, as well as contributions to global warming and other environmental factors. There are also risk factors associated with quality of information, uncertainty of data, and economics factors including feasibility and availability.

Do not require that substitutes be risk-free to be found acceptable

The Agency finds substitutes to be acceptable, acceptable in restrictions, or unacceptable by the Agency. For substitutes to be found acceptable they must have a reduced risk, which is not necessarily risk free.

Restrict those substitutes that are significantly worse

The EPA does not intend to restrict a substitute if it has only marginally greater risk. Drawing fine distinctions would be extremely difficult. The Agency also does not want to intercede in the market's choice of available substitutes, unless a substitute has been proposed or is being used that the Agency considers more harmful to human health and the environment than other available or potentially alternatives. EPA's basis for this comparison matures as the suite of alternatives and knowledge of risks changes.

Evaluate risks by use

Section 612 requires that substitutes be evaluated by use. Environmental and human health exposures can vary significantly depending on the particular application of a substitute. Thus, the risk characterizations must be designed to represent differences in the environmental and human health effects associated with diverse uses. This approach cannot, however, imply fundamental tradeoffs with respect to different types of risk to either the environment or to human health.

Provide the regulated community with information as soon as possible

The Agency recognizes the need to provide the regulated community with information on the acceptability of various substitutes as soon as possible.

Do not endorse products manufactured by specific companies

The Agency does not issue company-specific product endorsements. In many cases, the Agency may base its analysis on data received on individual products, but addition of an alternative to the acceptable list based on that analysis does not represent endorsement of that company's products.

Defer to other environmental regulations when warranted

In some cases, EPA and other federal agencies have developed extensive regulations under other statutes or other parts of the CAA that address any potential cross- or inter-media transfers that result from the alternatives to class I and class II substances. The SNAP program takes existing regulations into account.

As this information indicates, central to the SNAP evaluation is the intersection between what an alternative is and in what end use it will be used. Section 612 establishes that basis.

What is EPA proposing?

Through this action, EPA is proposing to modify previous determinations of acceptability to list certain alternatives as unacceptable. EPA is taking this action for several reasons. In some cases, if these substitutes were presented to the Agency at this point in time, with the current information EPA has about the suite of available and potentially available alternatives, and the current understanding of the criteria SNAP uses to evaluate alternatives, it is not likely that EPA would have listed these alternatives as acceptable. Secondly, EPA is taking this action because in some cases, when EPA reviews the criterion concerning other regulations, EPA recognizes that these alternatives are further restricted and thus the SNAP listing is not consistent with those other regulations.

EPA is proposing to modify the listings for certain aerosols, foams, [solvents, fire suppression] and refrigerants. These listings include both HCFCs and HFCs.

Why is EPA Modifying the Listings for HCFCs?

Section 605(a) of the Act as amended explicitly prohibits the introduction into interstate commerce or use of any class II substance unless such substance:

- (1) Has been used, recovered, and recycled;
- (2) is used and entirely consumed (except for trace quantities) in the production of other chemicals;
- (3) is used as a refrigerant in appliances manufactured prior to January 1, 2020; or
- (4)

EPA's intent in proposing to modify the listing for HCFCs in various applications is based on this prohibition on sale and distribution and covers where HCFCs have been previously been listed as acceptable as aerosols, foam blowing agents, fire suppression and explosion protection, cleaning solvents, sterilants, and adhesives, coatings and inks. Further, recognizing that under Section 605 EPA is implementing the HCFC phaseout based on a "worst first approach" EPA is proposing to align the dates for modifications to the SNAP listings with the phaseout milestones. Thus, HCFC-141b, -142b and -22 will be modified more quickly than HCFC-225ca, -225cb, -124, and -123. Further information is provided in subsequent sections of this proposal and in the docket.

EPA is proposing through this action to modify the listings for certain HFCs and HFC blends in certain aerosol, foam blowing, and air conditioning and refrigeration end uses. EPA is considering the intersection between the specific HFC or HFC blend and the particular end use.

Through this action, EPA is not proposing that any specific HFCs are no longer acceptable or that for any specific sector, the only acceptable alternatives are HFC-free. Instead, consistent with SNAP's history and CAA Section 612, EPA is proposing these modifications based on the alternative being considered, the SNAP criteria for evaluation, and the current suite of available and potentially available alternatives. Additional information concerning these modifications can be found in subsequent sections of this action.

How Does This Action Relate to Petitions To Delist HFC-134a?

Summary of Petitions

EPA received three petitions concerning modifying the listing of HFC-134a. The first petition submitted on May 7, 2010. The petition was submitted by Natural Resources Defense Council (NRDC) also on behalf of Institute for Governance and Sustainable Development (IGSD), and Environmental Investigation Agency-US (EIA) were the organizations petitioning EPA. The petition requested that EPA remove HFC-134a from the list of acceptable substitutes for ozone-depleting substances (ODS) and moves it to the list of unacceptable substitutes. The petitioners requested this change for use of HFC-134a in new passenger cars and light duty trucks, non-medical aerosols and other uses for refrigeration and foam blowing. The petitioners stated there are other available alternatives for use in motor vehicle air conditioning (MVAC) and other sectors, and these other alternatives present much lower risks to human health and environment than HFC-134a. While initially found to be incomplete, on February 14, 2011, EPA found petition complete for MVAC in new passenger cars and light-duty vehicles and determined it was incomplete for other uses of HFC-134a. EPA noted in its response, that at a future date, EPA would initiate a notice and comment rulemaking in response to the petition. Noting in

particular, that EPA would evaluate and take comment on many factors, including, but not limited to, the time frame for introduction of newer alternatives for MVACs and potential lead time for manufacturers of motor vehicles to move to alternatives.

On April 26, 2012 EPA received a supplemental petition from EIA. EIA states that in light of the comparative nature of the SNAP program's evaluation of alternatives and given that other acceptable substitutes are on the market or soon to be available, the petitioner requested that EPA remove HFC-134a and HFC-134a blends from the list of acceptable alternatives for uses where EPA found CFCs and HCFCs to be nonessential under Section 610 of the Act. And, that the schedule for moving HFC-134a and HFC-134a blends from the list of acceptable to not acceptable alternatives be based on the "most rapidly feasible transitions to one or more of the" acceptable alternatives for each use. The petitioner noted that initial approved HFC-134a for a number of applications occurred in the 1990s and were based 1) HFC-134a does not contribute to ozone depletion; 2) HFC-134a's GWP and atmospheric lifetime were close to those of other alternatives that had been determined to be acceptable for the end-uses; and 3) HFC-134a is not flammable and its toxicity is low.⁴ The petitioner stated that the analysis may have been appropriate in the 1990s but was not true currently given the range of other available or potentially available alternatives. The petitioner requested that the nonessential products ban be extended to HFC-134a and HFC-134a blends for aerosols and pressurized dispensers (including tire inflators), foam blowing agents; novelty products (including propelled plastic party streamers, web string, artificial snow, specialty paints and "poop" freeze), noise horns (including marine safety noise horns, sporting event noise horns, personal safety noise horns, wall-mounted industrial noise horns used as alarms in factories and other work areas, and intruder noise horns

⁴ See, e.g., 60 Fed. Reg. at 31,097.

used as alarms in homes and cars); foam and refrigerants in new domestic refrigerators and freezers and other retail stand alone coolers and freezers; cleaning fluids for noncommercial electronic, photographic and other equipment.

EPA has not found this petition to be complete. EPA and the petitioner have exchanged further correspondence that can be found in the docket.

A petition from NRDC, EIA and IGSD was filed on April 27, 2012. The petitioners requested that EPA: 1) Remove HFC-134a from the list of acceptable substitutes for CFC-12 in household refrigerators and freezers and stand-alone retail food refrigerators and freezers; 2) Restrict the sales of SNAP listed refrigerants to all except certified technicians with access to service tools required under existing EPA regulations, and 3) Adopt a standardized procedure to determine the speed of transition from obsolete high-GWP HFCs to next-generations alternatives and substitutes.

The petitioners requested that EPA remove HFC-134a and all other refrigerants with 100-yr GWP>150 from the acceptable substitutes list for household refrigerators and freezers and stand-alone retail food refrigerators and freezers. NRDC and IGSD request that EPA remove HFC-134a and all other refrigerants with 100-yr GWP>150 from the acceptable substitutes list for household refrigerators and freezers and stand-alone retail food refrigerators and freezers.

According to the petitioners, HFC-134a has a chemical production cost of about \$8.00/kg and market price of about \$12 to \$18/kg when sold in small 500 gram cans. By comparison, the petitioners stated that HFO-1234yf has an expected chemical production cost of \$40 to \$50/kg which would be \$60 to \$90 per small 500 gram can. The petitioners considered the price difference as a potential incentive for motor vehicles manufactured to use HFO-1234yf to be serviced with HFC-134a which could result in higher GHG emissions. This could also lead to

cross contamination which could increase the cost of service because the mixed refrigerant must be removed from vehicles and reclaimed or destroyed. The petitioners stated that requiring service by technicians certified under Section 609 of the Act and with access to professional tools, these situations could be avoided.

The petitioners requested that EPA can create a “standardized transition strategy based on the date when the first low-GWP product enters the market, the date when the low-GWP product achieves a specific market penetration, the agility of the sector to transform its manufacturing facilities, and other market indicators.” The petitioners suggested that EPA may consider harmonizing transition schedules with other regulatory schedules and voluntary pledges made by private sector companies to avoid use and emissions of high-GWP refrigerants.

The petitioners further stated that HFC-134a be moved to the list of unacceptable substitutes for newly manufactured MVACs January 1, 2017 consistent with European Union regulations and indicated that this would correspond to the incentives under the joint rulemaking between EPA and NHTSA establishing fuel economy and emissions standards with credits for reducing MVAC leakage or adopting lower-GWP alternative refrigerants – credits that count towards compliance

For household refrigerators and freezers and stand-alone retail food refrigerators and freezers the petitioners suggest that EPA move HFC-134a to the list of unacceptable alternatives for new products 24 months after the first low-GWP model is offered for sale within each appliance category.

For aerosol products the petitioners support an approach that finds HFC-134a unacceptable for any aerosol products considered nonessential uses of Class I ODS (§82.66(a)); any aerosol products that are exempt from the ban on nonessential products if lower-GWP propellant alternatives or not-in-kind product substitutes are technically and economically feasible; and

3) for new products introduced after the CFC phase-out that would have used CFCs if available, but instead used HFC-134a.

EPA has not found this petition to be complete. EPA and the petitioner have exchanged further correspondence that can be found in the docket.

Today's Action

This action responds to the May 7, 2010 petition and is consistent with EPA's February 14, 2011 response. This action is further informed by both the supplemental petitions submitted in April 2012 as well as other information including but not limited to: scientific findings, information provided by the Technical and Economic Assessment Panel that supports the Montreal Protocol, journal articles, submissions to the SNAP program, the regulations and supporting dockets for other EPA rulemakings, presentations and reports presented at domestic and international conferences, trade associations and professional organizations, etc.



Nitrous Oxide (N₂O): The Dominant Ozone-Depleting Substance Emitted in the 21st Century

A. R. Ravishankara, *et al.*
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 Materials and Methods
 SOM Text
 Figs. S1 to S3
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Nitrous Oxide (N₂O): The Dominant Ozone-Depleting Substance Emitted in the 21st Century

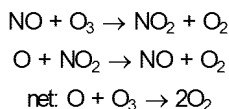
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By comparing the ozone depletion potential-weighted anthropogenic emissions of N₂O with those of other ozone-depleting substances, we show that N₂O emission currently is the single most important ozone-depleting emission and is expected to remain the largest throughout the 21st century. N₂O is unregulated by the Montreal Protocol. Limiting future N₂O emissions would enhance the recovery of the ozone layer from its depleted state and would also reduce the anthropogenic forcing of the climate system, representing a win-win for both ozone and climate.

The depletion of the stratospheric ozone layer by human-made chemicals, referred to as ozone-depleting substances (ODSs), was one of the major environmental issues of the 20th century. The Montreal Protocol on Substances That Deplete the Ozone Layer (1), MP, emerged from the Vienna Convention for the Protection of the Ozone Layer (2). The MP has been highly successful in reducing the emissions, growth rates, and concentrations of chlorine- and bromine-containing halocarbons, the historically dominant ODSs (3), and has limited ozone depletion and initiated the recovery of the ozone layer.

The relative contributions of various ODSs to ozone layer depletion are often quantified by the ozone depletion potential (ODP) (4). An ODP relates the amount of stratospheric ozone destroyed by the release of a unit mass of a chemical at Earth's surface to the amount destroyed by the release of a unit mass of chlorofluorocarbon 11, CFC-11 (CFCI₃). ODPs are widely used for policy formulation because of their simplicity in quantifying the relative ozone-destroying capabilities of compounds.

Through the work of Crutzen (5) and Johnston (6), nitrogen oxides (NO_x = NO + NO₂) are also known to catalytically destroy ozone via



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The primary source of stratospheric NO_x is surface N₂O emissions [(7) and references therein]. N₂O has been thought of as primarily a natural atmospheric constituent, but the influence of its changes on long-term changes in ozone concentrations has also been examined (8–10).

Nitrous oxide shares many similarities with the CFCs, historically the dominant ODSs. The CFCs and N₂O are very stable in the troposphere, where they are emitted, and are transported to the stratosphere where they release active chemicals that destroy stratospheric ozone through chlorine- or nitrogen oxide-catalyzed processes. They both have substantial anthropogenic sources. Unlike CFCs, N₂O also has natural sources, akin to methyl bromide, which is another important ODS. Assigning an ODP for N₂O and separating out the natural and anthropogenic emissions are therefore no more conceptually difficult than they are for methyl bromide.

In spite of these similarities between N₂O and previously recognized ODSs and in spite of the recognition of the impact of N₂O on stratospheric ozone, N₂O has not been considered to be an ODS in the same sense as chlorine- and bromine-containing source gases. The signatories to the Vienna Convention (2) have agreed in Article 2 (General Obligations) to "Adopt appropriate legislative or administrative measures ... to control, limit, reduce or prevent human activities under their jurisdiction or control should it be found that these activities have or are likely to have adverse effects resulting from modification or likely modification of the ozone layer." Yet N₂O remains unregulated by the MP (1).

Here, we present the ODP of N₂O to be positive and nonzero and show that N₂O is an ozone-

depleting substance on the basis of the extent of ozone depletion it causes. Indeed, current anthropogenic ODP-weighted N₂O emissions are the largest of all the ODSs and are projected to remain the largest for the rest of the 21st century.

We have calculated the ODP of N₂O by using the Garcia and Solomon two-dimensional (2D) model [(11) and references therein], which is similar to models used previously for such calculations (12, 13). The ODP of N₂O under current atmospheric conditions is computed to be 0.017. This value is comparable to the ODPs of many hydrochlorofluorocarbons (HCFCs) (3) such as HCFC-123 (0.02), -124 (0.022), -225ca (0.025), and -225cb (0.033) that are currently being phased out under the MP. We conclude that the value of the ODP of N₂O is robust because (i) our similarly calculated ODPs for CFC-12 (1.03) and HCFC-22 (0.06) agree with the accepted values (3); (ii) ozone depletion by NO_x from N₂O dominates the chemical control of ozone in the mid-stratosphere (13), a region well represented with 2D models; and (iii) ozone reductions by enhanced N₂O have been reported in other studies (8, 10, 14), although no published study, to the best of our knowledge, has previously presented an ODP for N₂O.

We examine here a few important factors that influence the ODP of N₂O. At mid-latitudes, chlorine-catalyzed ozone destruction contributes most to depletion in the lowest and upper stratospheres, that is, below and above the ozone maximum. Nitrogen oxides contribute most to ozone depletion just above where ozone concentrations are the largest. This leads to efficient ozone destruction from NO_x (13). The ODP of N₂O is lower than that of CFCs primarily because only ~10% of N₂O is converted to NO_x, whereas the CFCs potentially contribute all their chlorine.

There are important interconnections between the roles of nitrogen oxides with chlorine such that the N₂O ODP may be different from the calculated value in the past and future. It is well known that nitrogen oxides dampen the effect of chlorine-catalyzed ozone destruction via the formation of ClONO₂, which ties up some of the chlorine in a benign form. However, as shown by Kinnison et al. (9), other reactions, such as the conversion of ClO to Cl by NO, can offset the damping.

We quantify the dependence of the ODP of N₂O on atmospheric concentrations of chlorine by calculating it for 1959 concentrations of strato-

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spheric Cl_y (essentially preindustrial). We find the ODP for 1959 to be 0.026, showing that Cl_y concentrations have a moderate effect on the efficiency of N_2O -caused ozone destruction. These results for the 1959 and 2000 Cl_y concentrations bracket the range expected for the rest of the 21st century; it shows that the N_2O 's ozone destructiveness per emitted unit mass should increase by about 50% when the stratospheric chlorine loading returns to preindustrial concentrations.

Nitrogen oxide chemistry is also dependent on odd hydrogen, bromine, and methane levels, but the dependence of N_2O 's ODP on these factors is expected to be much smaller than the effect of chlorine (13).

Whereas enhanced stratospheric sulfate aerosols after volcanic injections increase the effectiveness of chlorine to destroy ozone, they will decrease the effectiveness of NO_x emissions by sequestering the catalytically active NO_x in HNO_3 . Such an influence has been observed after the Mount Pinatubo eruption (15). Therefore, we anticipate that the ODP of N_2O will be reduced when the sulfate loading is enhanced. However, high volcanic sulfate loadings are unpredictable and sporadic, and their effects are short-lived, lasting only a few years. We assess the extent of their influence by calculating ODPs at peak sulfate loadings observed after the eruption of Mount Pinatubo (13, 16).

For the remaining discussion, we will use an ODP of 0.017 as though it were independent of atmospheric conditions, atmospheric composition, and time. This value is a conservative choice for the reasons discussed above.

It is important to note that the ODP alone cannot fully quantify the impact of a chemical that is released into the atmosphere. The entire emission history, and even the potential future emission projections, must be considered by using an extensive quantity like ODP-weighted emission as a metric rather than an intensive quantity such as ODP, which only considers the ozone depletion per unit mass. Figure 1 compares the anthropogenic N_2O emissions with those from the major ODSs (now controlled under the MP) for 1987 and 2008. It is clear that ODP-weighted anthropogenic emissions of N_2O were a substantial fraction of the ODP-weighted emissions of CFC-11, CFC-12, and CFC-113 even in 1987, just before the adoption of the MP. They were likely larger than the sum of the ODP-weighted emission of halons and were much larger than that of methyl bromide.

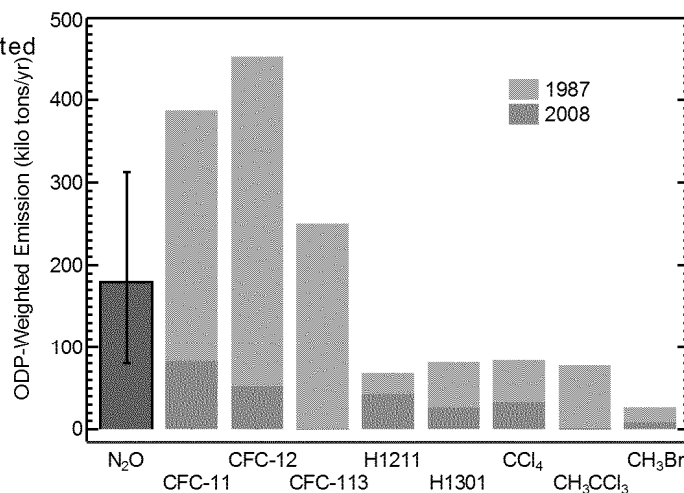
Even though N_2O 's ODP is only 0.017, roughly one-sixtieth of CFC-11's, the large anthropogenic emissions of N_2O more than make up for its small ODP, making anthropogenic N_2O emissions the single most important of the anthropogenic ODS emissions today (Fig. 1). For example, the global anthropogenic emission of N_2O now (produced mainly as a byproduct of fertilization, fossil fuel combustion and industrial processes, biomass and biofuel burning, and a few other processes) is roughly 10 million metric tons per year

compared with slightly more than a million metric tons from all CFCs at the peak of their emissions.

Figure 2 compares estimated ODP-weighted emissions of various ODSs controlled by the MP during the late 20th and all of the 21st centuries [see (13) for details of the calculation]. Recent estimates of expected future N_2O emissions under various greenhouse gas mitigation requirements continue to show that N_2O emissions are unlikely to be lower than they are today, even under the most stringent reduction requirements (17). From the top graph of Fig. 2, it is clear that N_2O is the largest ODS emission today and indeed is expected to remain the largest throughout the rest of this century for all of these emission scenarios. If anthropogenic N_2O emissions were to continue unabated, by 2050 they could represent an ODP-weighted emission in excess of 30% of the peak CFC ODP-weighted emissions of 1987. These fundamental conclusions on the influences of anthropogenic N_2O are not particularly sensitive to the uncertainties in the total anthropogenic emission rate or to the uncertainties in specific sectoral emissions (13).

It should be noted that the largest uncertainty in ODP-weighted emission comparisons comes from the uncertainties in the emission estimates of N_2O , rather than in the calculated ODP. The magnitudes of the sectoral emissions of N_2O , mostly from agricultural practices and industrial sources, are highly uncertain, but the total human-caused emissions are constrained by observed increases in N_2O concentrations and N_2O 's lifetime. The Intergovernmental Panel on Climate Change (IPCC)'s fourth assessment report estimates (18) a total annual emission during the 1990s of 17.7 TgN, of which 6.7 TgN (10.5 million metric tons of N_2O) were anthropogenic in origin.

Fig. 1. Comparison of annual N_2O ODP-weighted emissions from the 1990s [IPCC, 2007 (18, 23)] with emissions of other ozone-depleting substances in 1987, when the emissions of chlorine- and bromine-containing ODSs were near their highest amount, and for 2008. Emissions during 2008 were inferred from observations taken by the Global Monitoring Division, Earth System Research Laboratory, National Oceanic and Atmospheric Administration for CFC-11, CFC-12, Halon 1211 (H1211), Halon 1301 (H1301), and CH_3Br ; all other emissions are taken from WMO (3). ODPs for all, except N_2O , are assumed to be the semi-empirical ODPs from WMO (3). Even at the height of ODS emissions in the 1980s, annual anthropogenic N_2O emissions were the fourth most important. Currently, anthropogenic N_2O emissions represent the largest contribution to ozone-depleting gas emissions. HCFC-22, the most important CFC replacement, would fall below the 1987 amount of CH_3Br for both time periods if included in the figure. The N_2O error bar represents a bottom-up uncertainty range. The lower end of the range is calculated by summing the lowest emissions estimates, and the higher end by summing the highest estimates, of the various individual sources provided by the IPCC (18).



Nitrous oxide is a greenhouse gas and is controlled under the Kyoto Protocol; it may be controlled via future climate negotiations. Therefore, it is also interesting to compare the contribution of N_2O to climate forcing with the contributions of other major greenhouse gases. The bottom graph of Fig. 2 shows the CO_2 equivalent [100-year global warming potential (GWP) weighted] emissions of various non- CO_2 greenhouse gases. Among these gases, N_2O 's contribution to climate forcing is second only to methane and is already much larger than that of all currently recognized ODSs. These projections of ODP- and GWP-weighted N_2O emissions show that N_2O is an important gas for both the future ozone layer and climate. They also support, and now quantify, previous suggestions that reductions in N_2O emissions would benefit both the ozone layer and climate (10). Numerous N_2O mitigation options are currently available. Examples include more efficient use of fertilizer on cropland (19) and the capture and destruction of byproduct N_2O emissions in chemical processes (e.g., manufacturing adipic and nitric acids) (20). It may be more desirable to reduce nonindustrial N_2O emissions when its ozone layer depletion impact is considered in addition to its impact on climate.

The World Meteorological Organization/United Nations Environment Programme (WMO/UNEP) 2007 assessment (3) states that the largest single option available to hasten ozone layer recovery is the recapture and destruction of ODSs (mostly CFCs and halons) that are already produced but not yet emitted to the atmosphere, that is, the so-called banks. However, much of the banked halocarbons reside in applications that are generally not cost-effective to recover

(e.g., foams in buildings) or in applications with continued demand and unavailability of suitable replacements (e.g., halons for fire fighting and CFCs for medical uses). Based on our value of the ODP and the IPCC fourth assessment report emission estimates for N_2O , the total 2005 banks (3) of ODSs are equivalent to roughly 20 years of continued anthropogenic emissions of N_2O at today's rate. Thus, although policy decisions regarding banks of halons and CFCs do represent the largest option for ozone protection today, the effect of N_2O can be expected to dominate in the future as the banks of these ODSs are either released to the atmosphere or are captured and destroyed. Furthermore, the destruction of the existing ODS bank represents a one-time benefit, whereas reductions in N_2O emissions have the ability to continue providing benefits into the future.

We also point out that increases in anthropogenic N_2O emissions or decreases due to abatement strategies would affect a number of issues of importance to stratospheric ozone: (i) it would

affect the date for the recovery of the ozone layer; (ii) it would imply that the use of a single parameter such as equivalent effective stratospheric chlorine (EESC) to estimate the recovery of the ozone layer should be reevaluated; (iii) it would have implications for the recovery of the polar ozone hole that might differ from that of global ozone; (iv) N_2O could be an unintended by-product of enhanced crop growth for biofuel production (21) or iron fertilization to mitigate CO_2 emissions (22). Such an enhancement would lead to the unintended "indirect" consequence of ozone layer depletion and increased climate warming, as pointed out by Crutzen et al. (21).

For historical reasons, it is interesting to compare ozone depletion caused by anthropogenic N_2O emissions with that from the original projections for 500 U.S. supersonic transports (7), SSTs. The total increase in stratospheric NO_x by that fleet of SSTs is comparable to that from today's total anthropogenic N_2O emission, indicative of the significance of anthropogenic N_2O .

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25. We are extremely grateful to S. Solomon for helpful discussion, suggestions for improving the paper, and encouragement and also thank S. Montzka for helpful suggestions and S. Montzka and G. Dutton of the Global Monitoring Division/Earth System Research Laboratory for providing us with mixing ratio observations from which we could infer emission data for several ODSs in 2008 and for helpful discussions. This work was supported in part by NOAA's Climate Goal Program.

Supporting Online Material

www.sciencemag.org/cgi/content/full/1176985/DC1

Materials and Methods

SOM Text

Figs. S1 and S2

References

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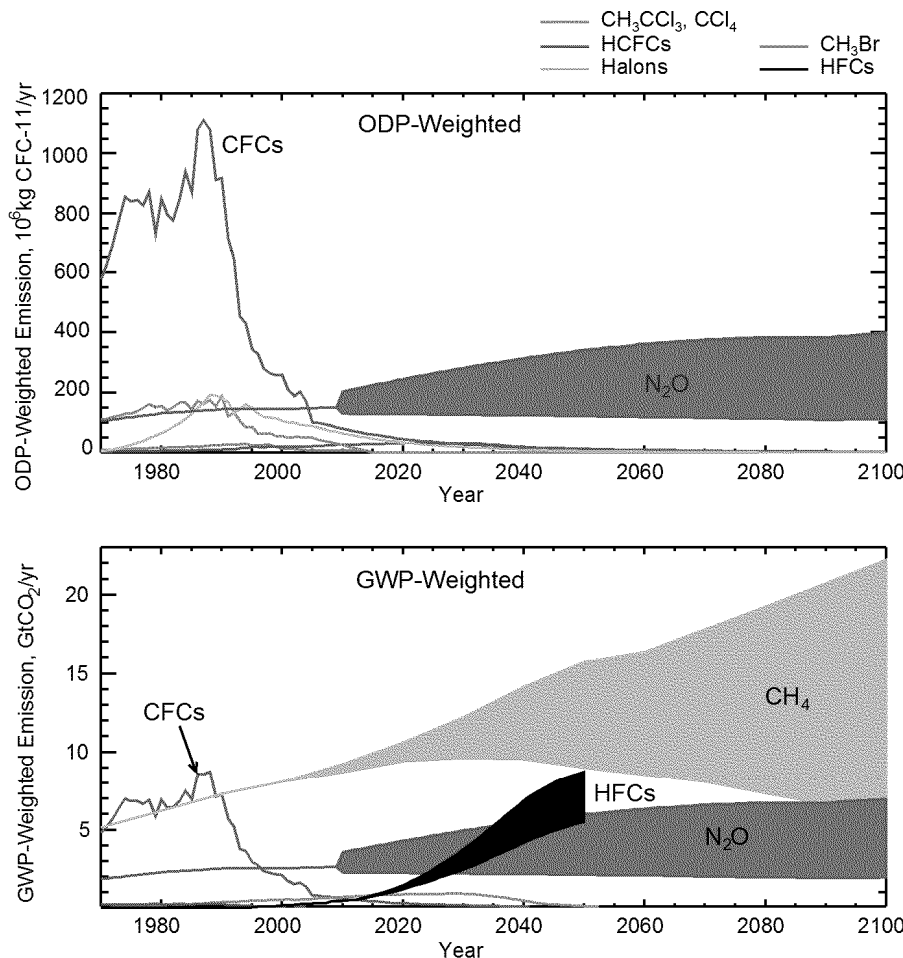


Fig. 2. Historical and projected ODP- and GWP-weighted emissions of the most important ODSs and non- CO_2 greenhouse gases. Non- N_2O ODS emissions are taken from WMO (3). Hydrofluorocarbon (HFC) projections are taken from Velders et al. (24), do not include HFC-23, and are estimated assuming unmitigated growth. The HFC band thus represents a likely upper limit for the contribution of HFCs to GWP-weighted emissions. CH_4 emissions represent the range of the Special Report on Emissions Scenarios (SRES) A1B, A1T, A1FI, A2, and B1 scenarios (23). The range of anthropogenic N_2O emissions is inferred from the mixing ratios of these same SRES scenarios [see (13) for details of calculation].

Desk Statement on Nitrous Oxide Article in *Science*

“Nitrous Oxide (N₂O): The Dominant Ozone-Depleting Substance Emitted in the 21st Century” by A.R. Ravishankara, John S. Daniel and Robert W. Portmann of NOAA

An article published in the journal *Science* today calculates the ozone-depletion potential (ODP) of nitrous oxide (N₂O) for the first time. The article then compares ODP-weighted emissions of N₂O from human activities with emissions of other ozone-depleting substances (ODS). With the exception of N₂O, most ODS such as chlorofluorocarbons (CFCs) are controlled by the international treaty to protect the ozone layer, the Montreal Protocol. CFCs and other fluorinated gases are produced for use in consumer and industrial applications while N₂O emissions come from a variety of sources, including agricultural fertilization and industrial production. Because of large reductions in emissions of other ODS – a result of successful efforts to eliminate production of these chemicals worldwide under the Montreal Protocol – the study concludes that N₂O is now the largest remaining uncontrolled ODS.

Results of this study underscore the complex relationship between ozone depletion and climate change. It has long been understood that N₂O damages ozone in the stratosphere, but because N₂O is also a climate-forcing gas, it is included in the “basket of gases” covered by the Kyoto Protocol, the international treaty addressing climate change. EPA will continue to work with leading scientists to better understand the implications of this study for future policies to protect the world’s atmosphere from both ozone layer depletion and climate change.

Findings and implications of the paper

“Nitrous Oxide (N₂O): The Dominant Ozone-Depleting Substance Emitted in the 21st Century” by A. R. Ravishankara, John S. Daniel, and Robert W. Portmann of NOAA

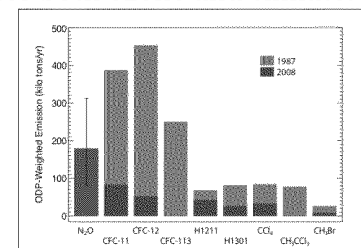
What is known about N₂O and nitrogen oxide-driven ozone layer depletion?

1. Based on the seminal work of Crutzen and Johnston, it has been known for nearly 40 years that nitrogen oxides cause ozone reductions and are involved in maintaining natural levels of ozone. Emission of nitrogen oxides from supersonic transport (aircraft) and the ensuing ozone depletion was the very first reason for the concern about anthropogenic impacts on the ozone layer.
2. It has been known for over 30 years that nitrous oxide (N₂O) is the primary source of nitrogen oxides in the stratosphere.
3. It is known that a significant fraction of the N₂O emissions are due to human activities such as agricultural fertilization and industrial production. The preindustrial level of N₂O was about 270 parts per billion (ppb), and the current level is roughly 325 ppb. Its concentration in the atmosphere continues to increase.
4. Many studies have examined what happens to the stratospheric ozone layer if nitrous oxide emissions are altered.

What is new from this study?

1. The study calculates the ozone depletion potential (ODP)—a relative measure of stratospheric ozone depleted by a unit mass emission of a gas relative to that for emission of a unit mass of chlorofluorocarbon-11—of N₂O to be roughly 0.017. This positive number is comparable to the ODPs of some of the HCFCs and implies that N₂O is an ozone-depleting gas. Although the literature widely supports that N₂O destroys ozone, to our knowledge, this is the first time N₂O is suggested to be an ozone-depleting substance in the way that other gases, already regulated under the Montreal Protocol, are.
2. More importantly, the study compares the ODP-weighted anthropogenic emissions of nitrous oxide with those of CFCs and other ozone-depleting substances. It shows that N₂O emissions in these terms were the fourth largest even at the height of the CFC emissions in 1987 prior to the Montreal Protocol. It also shows that N₂O is now, and is expected to be for the next century, the largest ozone depletion gas emission if the anthropogenic N₂O emissions are unabated.
3. The study compares the contribution of N₂O emissions to various other ODS controls that are envisaged and notes the large magnitude of N₂O's contribution to ozone depletion compared to those from other considered measures.
4. N₂O is also a greenhouse gas. The study notes that there would be climate AND ozone layer benefits to reductions in N₂O emissions— a “win-win” for both ozone and climate.

Bottom line: the dots were all there, but this study connected the dots to show that emissions of nitrous oxide are the most harmful to the ozone layer of all the substances being emitted today-- and will remain so for the 21st century under current policies.



Two important points that could cause confusions: (a) Even though N₂O depletes the global ozone layer, its impact on the ozone hole (the annual late-winter-springtime ozone loss in the Austral stratosphere) is negligible! This difference between CFCs and N₂O comes about because of interesting chemistry differences. This could be a major point of confusion to the public and the press. (b) Currently, stratospheric ozone depletion is dominated by ODSs already regulated by the Montreal Protocol, which have accumulated to large concentrations

Who should care about these results?

1. The general public, who should know that ozone layer depletion has been occurring ever since industrialization.
2. Policy makers who deal with ozone layer depletion policy and climate change policy. This includes many US agencies, US negotiators, US EPA, USDA, State Dept., etc. It also includes international institutions such the UNEP and WMO.
3. Scientists—because many assumptions about the dates for when the ozone layer depletion started, when the ozone layer will recover, and many other issues will have to be reexamined.

Some sensitivities (ones that we can think of now):

1. USDA may be very sensitive to this finding since the predominant sources of man-made N₂O emissions are from agricultural practices.
2. US EPA will be sensitive to this finding since it may have to declare N₂O an ozone-depleting gas and may have to regulate its emissions.
3. Many Nations will be sensitive to this because all have signed the Montreal Protocol and, now, an agriculture-related emission may have to be dealt with. It may also affect many choices in reductions that the countries have agreed to make and are likely to agree to make, for example the HFC phase down under the Montreal Protocol.

Policy Implications:

1. As an ozone-depleting substance N₂O may have to be considered under the Montreal Protocol and thereby require an amendment to the protocol. As a more important gas to climate change currently than the collection of HFCs, regulation of N₂O under both a climate agreement and the Montreal Protocol could pose challenges to negotiations.
2. Given the introduction of another ozone-depleting substance to the mix, nations may want to reexamine their strategies for phasing out other ODSs and their substitutes.
3. The increased potential regulation of many greenhouse gases under different treaties could call into question the basket of gases approach for climate gases.

N₂O

Background: A paper published in *Science* (2009, Ravishankara et al) calculates the ODP of nitrous oxide (N₂O). The paper compares ODP-weighted emissions of N₂O from human activities with emissions of other ozone-depleting substances (ODS). Because of the Montreal Protocol's success, the paper concludes that N₂O is now the largest remaining uncontrolled ODS. In the 2010 Science Assessment, the SAP further discussed the contributions of N₂O to ozone depletion and highlighting the growth in its relevant size. One of the lead authors is A.R. Ravishankara who is also the co-chair of the SAP.

The pre-industrial level of N₂O was about 270 parts per billion (ppb) while the current level is roughly 325 ppb. N₂O emissions come from a variety of sources, including agricultural fertilization and industrial production. Anthropogenic emissions of N₂O total approximately 6.7 TgNyr⁻¹ (IPCC, 2007). Agriculture is responsible for 2.8 TgNyr⁻¹ and related emissions from rivers, estuaries and coastal zones add a further 1.7 TgNyr⁻¹. Emissions associated with fossil fuel combustion and industrial activities, biomass burning, atmospheric deposition, and human excreta combined account for the remaining 2.2 TgNyr⁻¹.

Scientists have known for a long time that nitrogen oxides cause ozone reductions. Nitrogen oxides from supersonic transport (SST) were initially the primary anthropogenic source of concern for the ozone layer. Scientists have also known that N₂O is the primary source of nitrogen oxides in the stratosphere. Thus, this is not a new issue. In fact, N₂O has been considered by the SAP in previous Science Assessments as well. What is new is that the 2009 paper calculates an ODP of N₂O. While N₂O depletes the ozone layer, its impact on the ozone hole is negligible.

N₂O's ODP was calculated as being 0.017. The anthropogenic ODP-weighted emission of N₂O is larger than that of any current halogenated ODS emission; however, the ODP is more uncertain than for halogenated substances. The SAP provides the impact of a hypothetical N₂O emission phaseout on globally averaged total column ozone that can be compared with the impact of other ODS phase-outs on ozone. By comparing 2-D model results with Equivalent Effective Stratospheric Chlorine (EESC), despite its limitations, it is proportional to the calculated integrated total ozone depletion reductions arising from various hypothetical ODS policy actions.

Nitrous oxide is also a potent greenhouse gas and is included in the "basket of gases" under both the UNFCCC and the Kyoto Protocol. Like most ODS, particularly CFCs, N₂O emissions pose a dual impact to the ozone layer and climate system. Efforts to reduce emissions should have a dual environmental benefit too.

Position: It is not clear whether N₂O will receive any attention at MOP-23. At the OEWG it was included in the presentation of the assessment panels' synthesis report but no discussion ensued. The 2009 paper is still relatively new, and the 2010 Science Assessment was released in the spring. It is possible that some Parties may ask questions seeking additional information and with little or no intention of suggesting any need for a substantive dialogue. It also could be raised within the context of the quadrennial terms of reference for the SAP.

If appropriate, the United States could thank the SAP for raising important scientific findings to the Parties and express interest in learning more as we consider the recent Scientific Assessment and synthesis report more fully. We could acknowledge the significant and continuing contributions of NOAA and NASA scientists in advancing ozone layer and climate science.

If any detailed discussions ensue, we should strive to support advancements of ozone layer science but bound any discussion given it is unlikely that Parties have had time to consider this information in meaningful ways. We could note that sources of N₂O emissions differ from the sources of other ODS significantly and welcome more detailed discussions in the future.



Nitrous Oxide from Agricultural Sources: Potential Role in Greenhouse Gas Emission Reduction and Ozone Recovery

Kelsi Bracmort

Analyst in Agricultural Conservation and Natural Resources Policy

October 26, 2009

Congressional Research Service

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CRS Report for Congress

Prepared for Members and Committees of Congress

Summary

Gases other than carbon dioxide accounted for nearly 15% of U.S. greenhouse gas emissions in 2007, yet there has been minimal discussion of these other greenhouse gases in climate and energy legislative initiatives. Reducing emissions from non-carbon dioxide greenhouse gases, such as nitrous oxide (N₂O), could deliver short-term climate change mitigation results as part of a comprehensive policy approach to combat climate change.

Nitrous oxide is 298 times more potent than carbon dioxide in its ability to affect climate change; and moreover, results of a recent scientific study indicate that nitrous oxide is currently the leading ozone-depleting substance being emitted. Thus, legislation to restrict nitrous oxide emissions could contribute to both climate change protection and ozone recovery.

The primary human source of nitrous oxide is agricultural soil management, which accounted for two-thirds of the N₂O emissions reported in 2007 (approximately 208 million metric tons CO₂ equivalent). One proposed strategy to lower N₂O emissions is more efficient application of synthetic fertilizers. However, further analysis is needed to determine the economic feasibility of this approach as well as techniques to measure and monitor the adoption rate and impact of N₂O emission reduction practices for agricultural soil management.

As Congress considers legislation that would limit greenhouse gas emissions (both H.R. 2454 and S. 1733 would require that greenhouse gas emissions be reduced by 83% in 2050), among the issues being discussed is how to address emissions of non-CO₂ greenhouse gases. Whether such emissions should be subject to direct regulation, what role EPA should play using its existing Clean Air Act authority, whether the sources of N₂O should be included among the covered entities of a cap-and-trade system, whether N₂O reductions should be considered offsets to be purchased by the covered entities of a cap-and-trade system, and what role USDA should play in any N₂O reduction scheme are among the issues being discussed. How these issues are resolved will have important implications for agriculture, which has taken a keen interest in climate change legislation.

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Introduction

Policymakers are dedicating considerable attention to climate change mitigation, primarily discussing options for carbon dioxide (CO₂) emission reduction.¹ Less frequently addressed in proposed legislation is emission reduction for non-CO₂ greenhouse gases, such as nitrous oxide (N₂O). However, N₂O reduction efforts have the potential to mitigate climate change. Moreover, N₂O emission sources may be regulated under the existing Clean Air Act as a class I or class II ozone-depleting substance at the discretion of the Environmental Protection Agency (EPA) Administrator. No new legislation needs to be passed to regulate N₂O for climate protection and ozone recovery.

The five non-CO₂ greenhouse gases regularly monitored but not entirely regulated by EPA (methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride) accounted for nearly 15% of U.S. greenhouse gas (GHG) emissions in 2007, as measured by total tons of CO₂ equivalent.² Nitrous oxide—the third-most abundant greenhouse gas—was responsible for roughly 4% of total U.S. GHG emissions in 2007 by weight. Although they comprise a smaller portion of GHG emissions, non-CO₂ greenhouse gases, including N₂O, are more potent than CO₂. The gases identified above are 25 to 22,800 times more effective than an equivalent weight of CO₂ at trapping heat in the atmosphere, with N₂O being 298 times more potent by weight.³

In addition to being one cause of climate change, N₂O is an ozone-depleting substance (ODS).⁴ Indeed, scientific analysis suggests that N₂O is now the leading ODS being emitted, as emissions of other substances have been reduced significantly owing to regulations enacted in the late 1980s, in the Montreal Protocol on Substances that Deplete the Ozone Layer.⁵ N₂O emission reduction could thus play a compelling role in recovery of the ozone layer as well as in climate change remediation.

The agriculture sector is the primary anthropogenic source of nitrous oxide.⁶ The bulk of U.S. N₂O emissions stem from fertilizing agricultural soils for crop production. Strategies or

¹ For more information on CO₂ emission reduction techniques, see CRS Report RL33801, *Carbon Capture and Sequestration (CCS)*, by Peter Folger. For more information on legislative proposals to address climate change and regulation of greenhouse gases under the Clean Air Act, see CRS Report R40556, *Market-Based Greenhouse Gas Control: Selected Proposals in the 111th Congress*, by Jonathan L. Ramseur, Larry Parker, and Brent D. Yacobucci; and CRS Report R40585, *Climate Change: Potential Regulation of Stationary Greenhouse Gas Sources Under the Clean Air Act*, by Larry Parker and James E. McCarthy.

² U.S. Environmental Protection Agency, *2009 U.S. Greenhouse Gas Inventory Report*, EPA 430-R-09-004, April 2009, <http://epa.gov/climatechange/emissions/usinventoryreport.html>.

³ The potency of a greenhouse gas is described by its global warming potential (GWP), an estimate of how much a greenhouse gas affects climate change over a quantity of time relative to CO₂, which has a GWP value of 1. Intergovernmental Panel on Climate Change, *Climate Change 2007: The Physical Science Basis* (2007), p. 212.

⁴ An ozone-depleting substance is a compound that contributes to stratospheric ozone depletion by releasing chlorine or bromine atoms into the atmosphere when broken down, leading to the destruction of ozone, a substance necessary to prevent harmful UVB rays from reaching Earth.

⁵ The Montreal Protocol is an international treaty crafted to protect the stratospheric ozone layer by gradually eliminating a number of ozone-depleting substances.

⁶ Also in the agriculture sector, animal digestive systems and manure management account for a large portion of U.S. methane emissions. The Intergovernmental Panel on Climate Change (IPCC) assigns nitrous oxide and methane a global warming potential of 298 and 25, respectively.

technologies designated for N₂O emission reduction are limited.⁷ This is partly due to the dispersed nature of N₂O emission sources.

In the agriculture sector, the majority of N₂O is released as a consequence of specific nitrogen cycle processes (nitrification and denitrification) when large amounts of synthetic nitrogen fertilizers are used for crop production. More efficient application of synthetic fertilizers (e.g., precision agriculture, nitrogen inhibitors, nitrogen sensors, controlled-release fertilizer products) is one way to reduce excess amounts of nitrogen available for bacterial processing and eventual release to the atmosphere as N₂O. High costs and difficulty in measuring these products' efficacy, among other deterrents, have hampered widespread adoption of practices to reduce N₂O emissions.

This report focuses on the contributions of N₂O to climate change and ozone depletion. Policy options for N₂O emission reduction, sources of N₂O, and federal support to lower N₂O emissions are discussed.

Nitrous Oxide: A Primer

Nitrous oxide (N₂O), familiar to some as “laughing gas,” contributes to climate change and ozone depletion. Once released, N₂O lingers in the atmosphere for decades (its atmospheric lifetime is approximately 114 years) and is 298 times more effective at trapping heat in the atmosphere over a 100-year time frame than carbon dioxide (CO₂).⁸ N₂O emission quantity estimates have remained fairly constant over the last few years, hovering around 312 million metric tons carbon dioxide equivalent (CO₂e). See **Table 1**.

Table 1. U.S. Greenhouse Gas Emissions
(million metric tons CO₂e)

Gas / Source	2005	2006	2007	Avg. Contribution ^a
Carbon dioxide (CO ₂)	6,090.8	6,014.9	6,103.4	85%
Methane (CH ₄)	561.7	582.0	585.3	8%
Nitrous oxide (N ₂ O)	315.9	312.1	311.9	4%
Hydrofluorocarbons (HFCs)	116.1	119.1	125.5	1.7%
Perfluorocarbons (PFCs)	6.2	6.0	7.5	<1%
Sulfur hexafluoride (SF ₆)	17.9	17.0	16.5	<1%
Total	7,108.6	7,051.1	7,150.1	

Source: Environmental Protection Agency, 2009 *U.S. Greenhouse Gas Inventory Report*.

a. Average contribution to total U.S. greenhouse gas inventory based on data provided for 2005 to 2007.

⁷ Strategies and technologies for N₂O emission reduction are limited in comparison to resources expended for methane capture. Methane capture technologies, as well as financial and technical support, for point sources have been available for decades. For more information on methane capture, see CRS Report R40813, *Methane Capture: Options for Greenhouse Gas Emission Reduction*, by Kelsi Bracmort et al.

⁸ S. Solomon, D. Qin, and M. Manning et al., *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth, IPCC*, IPCC WG1 AR4 Report, New York, NY, 2007, <http://ipcc-wg1.ucar.edu/wg1/wg1-report.html>. The IPCC assigned N₂O a global warming potential of 298 over a 100-year time horizon.

Sources of N₂O Emissions

Nitrous oxide is emitted from anthropogenic (manmade) and natural sources. Oceans and natural vegetation are the major natural sources of N₂O. Agricultural soil management (e.g., fertilization, application of manure to soils, drainage and cultivation of organic soils) is responsible for two-thirds of anthropogenic U.S. N₂O emissions.⁹ In 2007, N₂O emissions from agricultural soil management totaled more than 200 million metric tons of CO₂e.¹⁰ Other anthropogenic sources of N₂O are combustion by mobile sources (cars, trucks, etc.), nitric acid production, and manure management.¹¹

Figure 1 depicts the origination and passage of nitrogen (N) that leads to N₂O emissions from agricultural soil management. The amount of N₂O emitted from cropland soils largely depends on the amount of nitrogen applied to a crop, weather, and soil conditions. Corn and soybean crops emit the largest amounts of N₂O, respectively, due to vast planting areas, plentiful synthetic nitrogen fertilizer applications, and, in the case of soybeans, high nitrogen fixation rates (**Figure 2**).¹²

The Nitrogen Cycle

Comprehension of the nitrogen cycle (**Figure 3**) is beneficial when crafting policy to reduce N₂O emissions from anthropogenic sources. Nitrogen, an essential element required by organisms to grow, is found throughout the atmosphere in various forms. The nitrogen cycle portrays the routes in which nitrogen moves through the soil and atmosphere in both organic and inorganic form. Certain processes within the nitrogen cycle convert the nitrogen into a form that can be taken up by plants. Four of the major processes are:

- nitrogen fixation—conversion of nitrogen gas (N₂) to a plant-available form;
- nitrogen mineralization—conversion of organic nitrogen to ammonia (NH₃);
- nitrification—conversion of ammonia (NH₃) to nitrate (NO₃⁻) via oxidation (that is, by being combined with oxygen); and
- denitrification—conversion of nitrates back to nitrogen gas.

Nitrous oxide is a byproduct of nitrification and denitrification. Both processes occur naturally. Excess application of nitrogen fertilizer can lead to increased nitrification, which can cause nitrate to leach into groundwater or surface runoff (in turn, this causes eutrophication, which can damage aquatic environments).

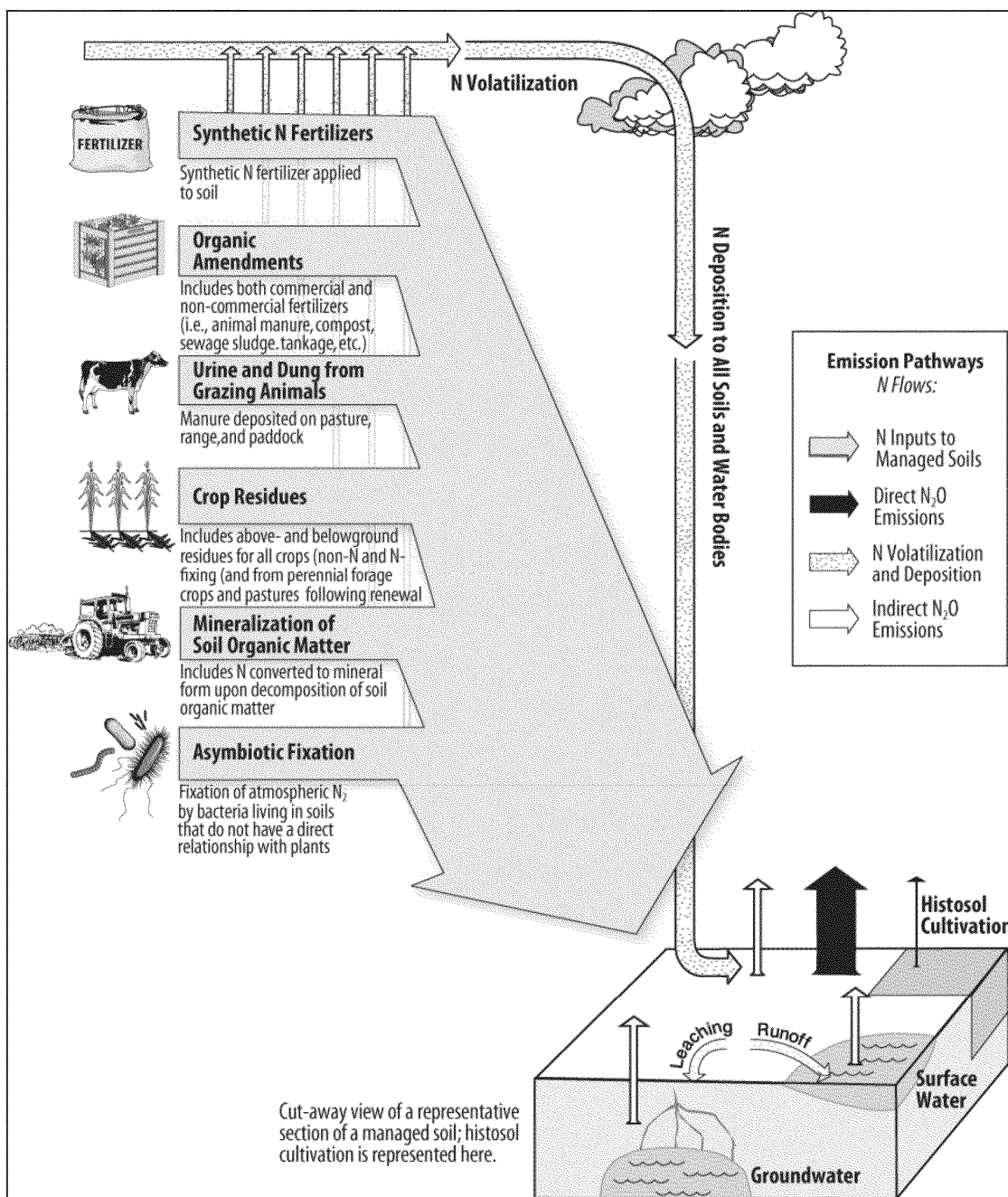
⁹ Agricultural soil management includes practices that add to, or create an environment conducive to the release of, mineral nitrogen (N).

¹⁰ U.S. Environmental Protection Agency, *2009 U.S. Greenhouse Gas Inventory Report*, EPA 430-R-09-004, April 2009, <http://epa.gov/climatechange/emissions/usinventoryreport.html>.

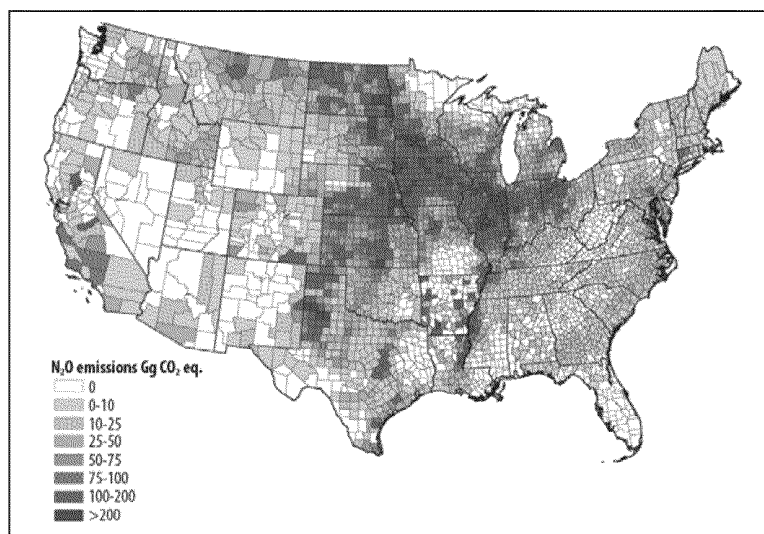
¹¹ Mobile (fuel) combustion leads to N₂O being emitted as a byproduct. N₂O is released as a byproduct during the oxidation of ammonia for production of nitric acid, a primary component of synthetic fertilizers and some explosives. N₂O emissions are generally released in large amounts from dry manure handling systems (e.g., pasture, solid storage).

¹² U.S. Department of Agriculture, *U.S. Agriculture and Forestry Greenhouse Gas Inventory: 1990-2005*, Technical Bulletin No. 1921, 2008, http://www.usda.gov/oce/global_change/AFGGInventory_1990_2005.htm. Nitrogen fixation is the conversion of nitrogen gas to ammonia.

Figure 1. Sources and Pathways of Nitrogen (N) Resulting in N₂O Emissions from Agricultural Soil Management

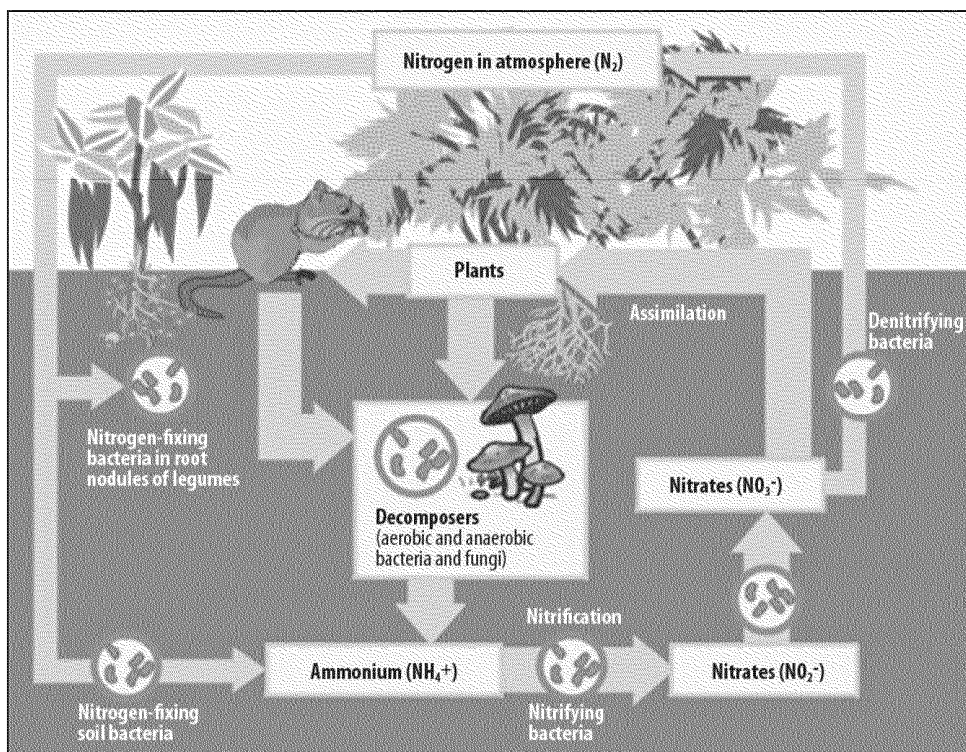


Source: U.S. Environmental Protection Agency, 2009 U.S. Greenhouse Gas Inventory Report, EPA 430-R-09-004, Chapter 6, April 2009. Adapted by CRS.

Figure 2. County-Level N₂O Emissions from Major Cropped Soils in 2005

Source: USDA, U.S. Agriculture and Forestry Greenhouse Gas Inventory: 1990-2005. Adapted by CRS.

Notes: 1 Gigagram (Gg) is equivalent to 1,000 metric tons. Major crops are defined as corn, soybean, wheat, hay, sorghum, and cotton.

Figure 3. The Nitrogen Cycle

Source: EPA. Adapted by CRS

Opportunities and Challenges for Nitrous Oxide Emission Reduction

N₂O emission mitigation options are available for agricultural soil management and nitric acid production. Nitric acid is a chemical compound used to make synthetic fertilizers. N₂O abatement options for nitric acid production include a high-temperature catalytic reduction method, a low-temperature catalytic reduction method, and nonselective catalytic reduction.¹³ The estimated reduction efficiencies (the percentage reduction achieved with adoption of a mitigation option) are 90%, 95%, and 85%, respectively.

Agricultural soil management mitigation options recommended by researchers and technology transfer specialists to discourage excess application of nitrogen fertilizers and soil disturbance (Table 2) are not generally being practiced. Fertilizer and soil best-management practices aim to provide the crop with the nutrient and soil conditions necessary for crop production, and prevent nutrient and soil loss from the crop field (e.g., erosion, leaching).¹⁴ Some may consider less money spent towards fertilizer use an economic incentive for agricultural producers.¹⁵ Others may be concerned to ensure that crop yields meet expected feed, fiber, and fuel mandates (e.g., for corn ethanol), which may be difficult to attain with less fertilizer use.¹⁶ Monitoring reduced nitrogen fertilization applications on a large scale for climate change mitigation purposes may be difficult; it is not clear how such a program could be managed at a national level.¹⁷ Enforcement options could include voluntary verification, third-party verifiers, or government intervention.

Reporting N₂O emissions from agricultural soil management was not included in the Final Mandatory Reporting of Greenhouse Gases Rule issued by EPA on September 22, 2009.¹⁸ EPA's reasoning behind this decision was that no low-cost or simple direct N₂O measurement methods exist. Additionally, EPA released a proposed rule requiring new or modified facilities that could trigger Prevention of Significant Deterioration (PSD) permitting requirements to apply for a revision to their operating permits to incorporate the best available control technologies and energy efficiency measures to minimize GHG emissions.¹⁹

¹³ U.S. Environmental Protection Agency, *Global Mitigation of Non-CO₂ Greenhouse Gases*, EPA-430-06-005, 2006. Catalytic reduction methods use a catalyst to reduce nitrous oxides in exhaust gas at varying temperatures.

¹⁴ C. S. Snyder, *Fertilizer Nitrogen BMPs to Limit Losses That Contribute to Global Warming*, International Plant Nutrition Institute, Ref. # 08057, June 2008, <http://www.ipni.net/ipniweb/portal.nsf/0/6D54ABC2C92D9AFA8525749B0074FF59>.

¹⁵ According to the Government Accountability Office, natural gas is the highest-priced factor when producing nitrogen fertilizer. Thus, natural gas prices impact nitrogen fertilizer costs. U.S. General Accounting Office, *Natural Gas: Domestic Nitrogen Fertilizer Production Depends on Natural Gas Availability and Prices*, GAO-03-1148, September 2003, <http://www.gao.gov/new.items/d031148.pdf>.

¹⁶ For example, the Renewable Fuel Standard (RFS) is a provision established by the Energy Policy Act of 2005 requiring gasoline to contain a minimum amount of fuel produced from renewable biomass (including corn). For more information on the RFS, see CRS Report R40155, *Selected Issues Related to an Expansion of the Renewable Fuel Standard (RFS)*, by Brent D. Yacobucci and Randy Schnepf.

¹⁷ For more information on monitoring carbon in agriculture, see CRS Report RS22964, *Measuring and Monitoring Carbon in the Agricultural and Forestry Sectors*, by Ross W. Gorte and Renée Johnson.

¹⁸ For more information on the agricultural implications of the Mandatory Reporting of Greenhouse Gases Rule, see CRS Report RL32948, *Air Quality Issues and Animal Agriculture: A Primer*, by Claudia Copeland.

¹⁹ For more information on the proposed PSD rule, see CRS Report R40585, *Climate Change: Potential Regulation of Stationary Greenhouse Gas Sources Under the Clean Air Act*, by Larry Parker and James E. McCarthy; and EPA, (continued...)

Table 2. Select N₂O Mitigation Alternatives for Agricultural Soil Management

Mitigation Alternative	Description
Split fertilization	Application of same amount of nitrogen fertilizer as in baseline but divided into three smaller increments during crop uptake period to better match nitrogen application with crop demand and reduce nitrogen availability for leaching, nitrification, denitrification, and volatilization.
Simple fertilization reduction (10%, 20%, or 30%)	Reduction of nitrogen-based fertilizer from one-time baseline application of 10%, 20%, or 30%.
Nitrification inhibitor	Reduces conversion of ammonium to NO ₃ ⁻ , which slows the immediate availability of nitrate (nitrate is water soluble). The inhibition of nitrification reduces nitrogen loss and increases overall plant uptake.
No-till	Conversion from conventional tillage to no-till, where soils are disturbed less and more crop residue is retained.

Source: EPA, *Global Mitigation of Non-CO₂ Greenhouse Gases*, http://www.epa.gov/climatechange/economics/downloads/GM_SectionV_Agriculture.pdf.

Federal Support for Nitrous Oxide Emission Reduction

USDA provides some financial and technical assistance for nutrient management through its conservation programs.²⁰ Moreover, USDA's Agricultural Research Service (ARS) is studying the relationship between agricultural management practices and nitrous oxide emissions.²¹

In addition to the agriculture sector, work is being done in the transportation sector to reduce N₂O emissions. Mobile combustion was responsible for nearly 10% of N₂O emissions reported in 2007.²² One N₂O emission reduction initiative, proposed by EPA and the Department of Transportation, is to cap tailpipe N₂O emissions at 0.010 grams per mile as part of a wider effort to reduce greenhouse gas emissions and improve fuel economy in tandem, via a CO₂ emission standard for light-duty vehicles.²³ EPA has allocated financial resources to quantify N₂O emissions for the greenhouse gas inventory (e.g., DAYCENT model).²⁴

(...continued)

Proposed Rule: Prevention of Significant Deterioration and Title V Greenhouse Gas Tailoring Rule, 2009, <http://www.epa.gov/NSR/fs20090930action.html>.

²⁰ For more information on agricultural conservation programs, see CRS Report R40763, *Agricultural Conservation: A Guide to Programs*, by Megan Stubbs. For more information on technical assistance for nutrient management, see USDA, Natural Resources Conservation Service, *Conservation Practice Standard—Nutrient Management Code 590*, August 2006, <ftp://ftp-fc.sc.egov.usda.gov/NHQ/practice-standards/standards/590.pdf>.

²¹ For more information on the efforts underway at ARS, visit the Air Quality of Agricultural Systems Research Unit website at http://www.ars.usda.gov/main/site_main.htm?modecode=36-25-15-15, or the Air Quality National Program website at http://www.ars.usda.gov/research/programs/programs.htm?NP_CODE=203.

²² U.S. Environmental Protection Agency, *2009 U.S. Greenhouse Gas Inventory Report*, EPA 430-R-09-004, April 2009, <http://epa.gov/climatechange/emissions/usinventoryreport.html>.

²³ U.S. Environmental Protection Agency, *EPA and NHTSA Propose Historic National Program to Reduce Greenhouse Gases and Improve Fuel Economy for Cars and Trucks*, EPA-420-F-09-047, September 2009, (continued...)

Policy Options for Nitrous Oxide Emission Reduction

Congress has begun to investigate the reduction of non-CO₂ greenhouse gas emissions, including N₂O emissions, as one strategy to mitigate climate change. Some contend that N₂O emissions reduction could serve as a short-term response in the larger, long-term scheme of mitigation and adaptation efforts.²⁵ It may be viewed as a short-term response because N₂O emissions make up a small amount of the GHG inventory compared to CO₂ emissions. Any substantial approach to mitigate climate change is likely at some point to have to address sources that emit CO₂.

Congress could approach N₂O emissions reduction as part of a comprehensive GHG emission strategy offering economically attractive abatement alternatives to discourage actions leading to climate change. For example, a cap or fee on N₂O emissions could spur innovative methods for agricultural producers to limit excess synthetic fertilizer application. Congress could also examine the tools necessary to identify N₂O emission abatement options, assess their cost, and determine their economic impact for full incorporation into climate change legislation.

Besides mitigating climate change, reducing N₂O emissions could lead to ozone recovery. Congress could explore the co-benefits that may arise from restricting N₂O emissions for climate change purposes. N₂O is not regulated as an ODS under the Clean Air Act, Title VI, Stratospheric Ozone Protection (as guided by the Montreal Protocol). As emissions of other ODSs (e.g., chlorofluorocarbon-11, halon-1211) have declined due to regulation, N₂O has emerged as the dominant ODS emission.²⁶ The first-ever published ozone depletion potential (ODP) value assigned to N₂O, 0.017, is less than the ODP value of 1.0 for the reference gas chlorofluorocarbon 11 (CFC-11). While some may not see a cause for alarm based on the ODP value alone, the quantity of N₂O emissions and its potency as a GHG can lead to serious harm (see **Table 1**).

The ODP value for N₂O does not allow for its mandatory inclusion as a class I substance for regulation under the Clean Air Act.²⁷ However, N₂O could be listed as a class II substance at the direction of the EPA Administrator or regulated under Section 615 of the act.²⁸ Class I substances have an ODP of 0.2 or more and are more harmful to stratospheric ozone molecules than Class II substances, which have an ODP of less than 0.2.

(...continued)

<http://www.epa.gov/otaq/climate/regulations/420f09047.htm>.

²⁴ EPA uses the DAYCENT ecosystem model for the U.S. greenhouse gas inventory “to estimate direct N₂O emissions from mineral cropland soils that are managed for production of major crops—specifically corn, soybeans, wheat, alfalfa hay, other hay, sorghum, and cotton.”

²⁵ Shilpa Rao and Keywan Riahi, “The Role of Non-CO₂ Greenhouse Gases in Climate Change Mitigation: Long-Term Scenarios for the 21st Century,” *Energy Journal*, vol. 27 (2006), pp. 1-26; Mario Molina, Durwood Zaelke, and K. Madhava Sarma et al., “Reducing Abrupt Climate Change Risk Using the Montreal Protocol and Other Regulatory Actions to Complement Cuts in CO₂ Emissions,” *Proceedings of the National Academy of Sciences of the United States of America*, October 12, 2009.

²⁶ A. R. Ravishankara, John S. Daniel, and Robert W. Portmann, “Nitrous Oxide (N₂O): The Dominant Ozone-Depleting Substance Emitted in the 21st Century,” *Science Express*, August 27, 2009.

²⁷ 42 U.S.C. § 7671a. The EPA Administrator may add to the list of class I substances any substances that the Administrator determines as having an ozone depletion potential of 0.2 or greater.

²⁸ 42 U.S.C. § 7671n. The EPA Administrator has the authority to promptly promulgate regulations respecting the control of an ODS by submitting notice of the proposal and promulgation of such regulation to the Congress.

With or without ODP substance listing, Congress may find it useful to incorporate the ozone depletion impacts of N₂O into its climate change policy proposals both to reduce greenhouse gas emissions and to further ozone recovery achievements. Classifying N₂O emission reduction as an eligible offset type, including N₂O as a covered entity within a cap-and-trade program, or directing EPA to use existing authority under the Clean Air Act to regulate N₂O are other available options to reduce N₂O emissions for ozone or climate protection. Any option chosen to reduce N₂O emissions will more than likely require an improvement of N₂O estimation, measurement, and reporting methods and possible financial incentives.

Congress could apply lessons learned from previous international agreements that are intended to abolish harmful compounds. The outcomes of the Montreal Protocol, put into action in the late 1980s, may prove useful to Congress in understanding the long-term implications of certain climate change policy options, specifically cap-and-trade. A number of gases were phased out under the Protocol, which allowed for each country to establish a regulatory framework to monitor and reduce ODSs. Certain ozone-depleting substances, such as N₂O, were not included in the Protocol partly because their threat was not perceived as urgent at the time. However, one unintended consequence of the success of the Protocol reducing targeted ODSs is that N₂O has emerged as the leading ODS.

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Report

Nitrous Oxide (N₂O): The Dominant Ozone-Depleting Substance Emitted in the 21st Century

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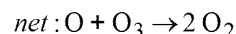
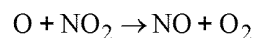
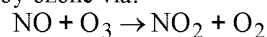
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By comparing the ozone depletion potential-weighted anthropogenic emissions of N₂O with those of other ozone depleting substances, ODSs, we show that N₂O emission currently is the single most important ODS emission and is expected to remain the largest throughout the 21st century. N₂O is unregulated by the Montreal Protocol. Limiting future N₂O emissions would enhance the recovery of the ozone layer from its depleted state, and would also reduce the anthropogenic forcing of the climate system, representing a 'win-win' for both ozone and climate.

The depletion of the stratospheric ozone layer by human-made chemicals, referred to as ozone-depleting substances (ODSs), was one of the major environmental issues of the 20th century. The Montreal Protocol on Substances that Deplete the Ozone Layer (1), MP, emerged from the Vienna Convention for the Protection of the Ozone Layer (2). The MP has been highly successful in reducing the emissions, growth rates, and concentrations of chlorine- and bromine-containing halocarbons, the historically dominant ODSs (3), and has limited ozone depletion and initiated the recovery of the ozone layer.

The relative contributions of various ODSs to the ozone layer depletion are often quantified by the ozone depletion potential (ODP) (4). An ODP relates the amount of stratospheric ozone destroyed by the release of a unit mass of a chemical at Earth's surface to the amount destroyed by the release of a unit mass of chlorofluorocarbon 11, CFC-11 (CFCl₃). ODPs are widely used for policy formulation due to their simplicity in quantifying the relative ozone-destroying capabilities of compounds.

Through the work of Crutzen (5) and Johnston (6), nitrogen oxides (NO_x = NO + NO₂) are also known to catalytically destroy ozone via:



The primary source of stratospheric NO_x is surface N₂O emissions ((7) and references therein). N₂O has been thought

of as primarily a natural atmospheric constituent but the influence of its changes on long-term changes in ozone levels has also been examined (8-10).

Nitrous oxide shares many similarities with the CFCs, historically the dominant ODSs. The CFCs and N₂O are very stable in the troposphere, where they are emitted, and transported to the stratosphere where they release active chemicals that destroy stratospheric ozone through chlorine- or nitrogen oxide-catalyzed processes. They both have significant anthropogenic sources. Unlike CFCs, N₂O also has natural sources, akin to methyl bromide, which is another important ODS. Assigning an ODP for N₂O, and separating out the natural and anthropogenic emissions is therefore no more conceptually difficult than it is for methyl bromide.

In spite of these similarities between N₂O and previously recognized ODSs, and in spite of the recognition of the impact of N₂O on stratospheric ozone, N₂O has not been considered to be an ODS in the same sense as chlorine- and bromine-containing source gases. The signatories to the Vienna Convention (2) have agreed in Article 2 (General obligations) to "Adopt appropriate legislative or administrative measures ... to control, limit, reduce or prevent human activities under their jurisdiction or control should it be found that these activities have or are likely to have adverse effects resulting from modification or likely modification of the ozone layer." Yet, N₂O remains presently unregulated by the Montreal Protocol (1).

Here we present the ODP of N₂O to be positive and non-zero and show that N₂O is an ozone depleting substance based on the extent of ozone depletion it causes. Indeed, current anthropogenic ODP-weighted N₂O emissions are the largest of all the ODSs and are projected to remain the largest for the rest of 21st century.

We have calculated the ODP of N₂O using the Garcia and Solomon 2D model ((11) and references therein), which is similar to models used previously for such calculations (12) (see Supporting online material, SOM). The ODP of N₂O under current atmospheric conditions is computed to be 0.017. This value is comparable to the ODPs of many HCFCs (3) such as HCFC-123 (0.02), -124 (0.022), -225ca (0.025),

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and -225cb (0.033) that are currently being phased out under the MP. We conclude that the value of the ODP of N_2O is robust because: (1) our similarly calculated ODPs for CFC-12 (1.03) and HCFC-22 (0.06) agree with the accepted values (3), (2) ozone depletion by NO_x from N_2O dominates the chemical control of ozone in the mid-stratosphere (see SOM), a region well represented with 2D models, and (3) ozone reductions by enhanced N_2O have been reported in other studies (8, 10, 13), even though no published study, to the best of our knowledge, has previously presented an ODP for N_2O .

We examine here a few important factors that influence the ODP of N_2O . At mid-latitudes chlorine-catalyzed ozone destruction contributes most to depletion in the lowest and upper stratospheres, i.e., below and above the ozone maximum. Nitrogen oxides contribute most to ozone depletion just above where ozone levels are the largest. This leads to efficient ozone destruction from NO_x (see SOM). The ODP of N_2O being lower than that of CFCs primarily because only ~10% of N_2O is converted to NO_x , while the CFCs potentially contribute all their chlorine.

There are important interconnections between the roles of nitrogen oxides with chlorine such that the N_2O ODP may be different from the calculated value in the past and future. It is well known that nitrogen oxides dampen the effect of chlorine-catalyzed ozone destruction via the formation of $ClONO_2$, which ties up some of the chlorine in a benign form. However, as shown by Kinnison *et al.* (9), other reactions such as the conversion of ClO to Cl by NO , can offset the damping.

We quantify the dependence of the ODP of N_2O on atmospheric levels of chlorine by calculating it for 1959 levels of stratospheric Cl_y (essentially pre-industrial). We find the ODP for 1959 to be 0.026, showing that Cl_y levels have a moderate effect on the efficiency of N_2O -caused ozone destruction. These results for the 1959 and 2000 Cl_y levels bracket the range expected for the rest of the 21st century; it shows that the N_2O 's ozone destructiveness per emitted unit mass should increase by about 50% when the stratospheric chlorine loading returns to preindustrial levels.

Nitrogen oxide chemistry is also dependent on odd hydrogen, bromine, and methane levels, but the dependence of N_2O 's ODP on these factors is expected to be much smaller than the effect of chlorine (See SOM).

While enhanced stratospheric sulfate aerosols following volcanic injections increase the effectiveness of chlorine to destroy ozone they will decrease the effectiveness of NO_x emissions by sequestering the catalytically active NO_x in HNO_3 . Such an influence has been observed following Mt. Pinatubo eruption (14). Therefore, we anticipate that the ODP of N_2O will be reduced when the sulfate loading is enhanced. However, high volcanic sulfate loadings are unpredictable

and sporadic, and their effects are short-lived, lasting only a few years. We assess the extent of their influence by calculating ODPs at peak sulfate loadings observed after the eruption of Mt. Pinatubo (15) (see SOM).

For the remaining discussion, we will use an ODP of 0.017 as though it were independent of atmospheric conditions, atmospheric composition, and time. This value is a conservative choice because the reasons discussed above.

It is important to note that the ODP alone cannot fully quantify the impact of a chemical that is released into the atmosphere. The entire emission history, and even the potential future emission projections, must be considered by using an extensive quantity like ODP-weighted emission as a metric rather than an intensive quantity such as ODP, which only considers the ozone depletion per unit mass. Figure 1 compares the anthropogenic N_2O emissions with those from the major ODSs (now controlled under the MP) for 1987 and 2008. It is clear that ODP-weighted anthropogenic emissions of N_2O were a significant fraction of the ODP-weighted emissions of CFC-11, CFC-12, and CFC-113 even in 1987, just prior to the adoption of the Montreal Protocol. They were likely larger than the sum of the ODP-weighted emission of Halons and were much larger than that of methyl bromide.

Even though N_2O 's ODP is only 0.017, roughly one sixtieth of CFC-11's, the large anthropogenic emissions of N_2O more than make up for its small ODP, making it the single largest ozone depleting substance emitted today, Fig. 1. For example, the global anthropogenic emission of N_2O now (produced mainly as a byproduct of fertilization, fossil fuel combustion and industrial processes, biomass and biofuel burning, and a few other processes) is roughly 10 million tonnes per year compared to slightly more than a million tonnes from all CFCs at the peak of their emissions.

Figure 2 compares estimated ODP-weighted emissions of various ODSs controlled by the MP during the late 20th and all of the 21st centuries (see SOM for details of the calculation). Recent estimates of expected future N_2O emissions under various greenhouse gas mitigation requirements continue to show that N_2O emissions are unlikely to be lower than today, even under the most stringent reduction requirements (16). It is clear that N_2O is the largest ODS emission today and indeed is expected to remain the largest throughout the rest of this century for all of these emission scenarios. If anthropogenic N_2O emissions were to continue unabated, by 2050 they could represent an ODP-weighted emission in excess of 30% of the peak CFC ODP-weighted emissions of 1987. These fundamental conclusions on the influences of anthropogenic N_2O are not particularly sensitive to the uncertainties in the total anthropogenic emission rate or to the uncertainties in specific sectoral emissions. (See SOM)

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It should be noted that the largest uncertainty in ODP-weighted emission comparisons comes from the uncertainties in the emission estimates of N_2O , rather than in the calculated ODP. The magnitudes of the sectoral emissions of N_2O , mostly from agricultural practices and from industrial sources, are highly uncertain; but the total human-caused emissions are constrained by observed increases in N_2O concentrations and N_2O 's lifetime. IPCC AR4 estimates (17) a total annual emission during the 1990s of 17.7 TgN, of which 6.7 TgN (10.5 million metric tons N_2O) were anthropogenic in origin.

Nitrous oxide is a greenhouse gas and is controlled under the Kyoto Protocol; it may be controlled via future climate negotiations. Therefore, it is also interesting to compare the contribution of N_2O to climate forcing with the contributions of other major greenhouse gases. The bottom panel of Figure 2 shows the CO_2 equivalent (100-year GWP weighted) emissions of various non- CO_2 greenhouse gases. Among these gases N_2O 's contribution to climate forcing is second only to methane and is already much larger than that of all currently recognized ODSs. These projections of ODP- and GWP-weighted N_2O emissions show that N_2O is an important gas for both future ozone and climate. They also support, and now quantify, previous suggestions that reductions in N_2O emissions would benefit both the ozone layer and climate (10). Numerous N_2O mitigation options are currently available. Examples include more efficient use of fertilizer on cropland (18) and the capture and destruction of byproduct N_2O emissions in chemical processes (e.g., manufacturing adipic and nitric acids) (19). It may be more desirable to reduce non-industrial N_2O emissions when its ozone layer depletion impact is considered in addition to its impact on climate.

The WMO/UNEP 2007 assessment states that the largest single option available to hasten ozone layer recovery is the recapture and destruction of ODSs (mostly CFCs and Halons) that are already produced but not yet emitted to the atmosphere, i.e., the so-called banks. However, much of the banked halocarbons reside in applications that are generally not cost-effective to recover (e.g., foams in buildings) or in applications with continued demand and unavailability of suitable replacements (e.g., Halons for fire fighting and CFCs for medical uses). Based on our value of the ODP and the IPCC AR4 emission estimates for N_2O , the total 2010 projected banks (3) of ODSs are equivalent to roughly 17 years of continued anthropogenic emissions of N_2O at today's rate. Thus, while policy decisions regarding banks of Halons and CFCs do represent the largest option for ozone protection today, the effect of N_2O can be expected to dominate in the future as the banks of these ODSs are either released to the atmosphere or are captured and destroyed. Furthermore, the destruction of the existing ODS bank represents a one-time

benefit, while reductions in N_2O emissions have the ability to continue providing benefits into the future.

A few other points are worthy of note. (1) Increases in anthropogenic N_2O emissions or decreases due to abatement strategies would affect a number of issues of importance to stratospheric ozone: (a) it would affect the date for the recovery of the ozone layer; (b) it would imply that the use of a single parameter such as Equivalent Effective Stratospheric Chlorine, EESC, to estimate the recovery of the ozone layer should be reevaluated; (c) it would have implications for the recovery of the polar ozone hole that might differ from that of global ozone. (2) N_2O could be an unintended byproduct of enhanced crop growth for biofuel production (20) or iron fertilization to mitigate CO_2 emissions (21). Such an enhancement would lead to the unintended 'indirect' consequence of ozone layer depletion and increased climate forcing by an alternative fuel used to curb global warming, as pointed out by Crutzen *et al.* (20) For historical reasons, it is interesting to compare ozone depletion caused by anthropogenic N_2O emissions with that from the original projections for 500 US supersonic transport (7), SSTs. The total increase in stratospheric NO_x by that fleet of SSTs is comparable to that from today's total anthropogenic N_2O emission, indicative of the significance of anthropogenic N_2O .

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chlorine- and bromine-containing ODSs were near their highest level, and for 2008. Emissions during 2008 were inferred from observations taken by the Global Monitoring Division, Earth System Research Laboratory, NOAA for CFC-11, CFC-12, Halon 1211 (H1211), Halon 1301 (H1301) and CH₃Br; all other emissions are taken from WMO (3)). ODPs for all, except N₂O, are assumed to be the semi-empirical ODPs from WMO (3). Even at the height of ODS emissions in the 1980s, anthropogenic N₂O was the fourth most significant ODS. Currently, anthropogenic N₂O emissions represent the largest contribution to ozone depletion. HCFC-22, the most significant CFC replacement, would fall below the 1987 level of CH₃Br for both time periods if included in the figure.

Fig. 2. Historical and projected ODP- and GWP-weighted emissions of the most important ODSs and non-CO₂ greenhouse gases. Non-N₂O ODS emissions are taken from WMO (3). HFC projections are taken from Velders *et al.* (23), do not include HFC-23, and are estimated assuming unmitigated growth. The HFC band thus represents a likely upper limit for the contribution of HFCs to GWP-weighted emissions. CH₄ emissions represent the range of the SRES A1B, A1T, A1FI, A2, and B1 scenarios (22). The range of anthropogenic N₂O emissions is inferred from the mixing ratios of these same SRES scenarios (See SOM for details of calculation).

Supporting Online Material

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Materials and Methods

SOM Text

Figs. S1 to S2

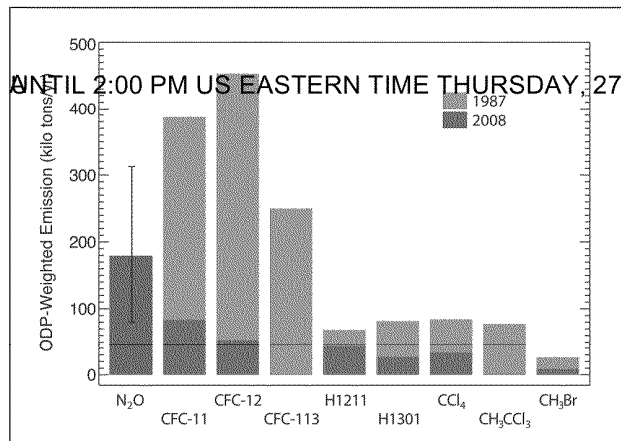
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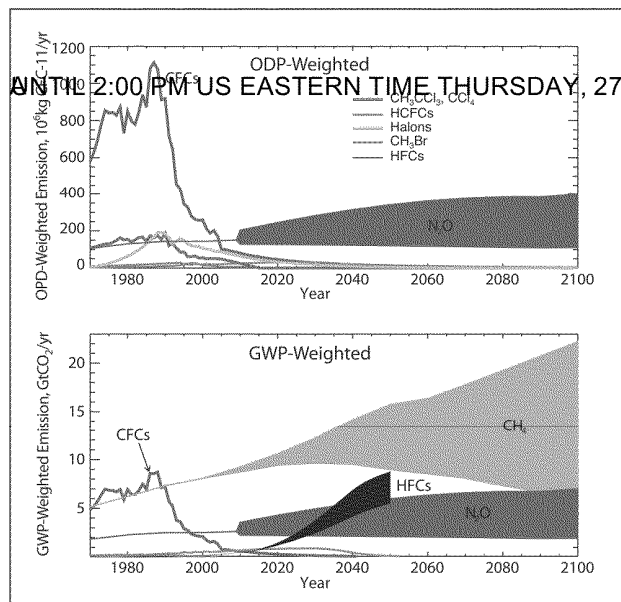
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Fig. 1. Comparison of annual N₂O ODP-weighted emissions from the 1990s (IPCC, 2007 (17, 22)) with emissions of other ozone depleting substances in 1987, when the emissions of





Supporting Online Material

Nitrous Oxide (N₂O): The dominant ozone depleting substance emitted in the 21st Century

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The following supplementary material provides additional details about our ozone depletion potential, ODP, calculations, factors affecting the ODP of N₂O, uncertainties unique to the calculation of the ODP of N₂O, our method of inferring N₂O emissions, and a comparison of the contributions of the sectoral N₂O emissions with the emissions of methyl bromide.

ODP Calculation and Important Factors

The Ozone Depletion Potential (ODP) of some ozone depleting substance, ODS, is defined by the time-integrated change of global ozone due to a unit mass emission of the ODS relative to that of CFC-11. We use steady state calculations to compute the ozone changes since our model incorporates a mixing ratio lower boundary condition rather than an emission boundary condition. The ODP of compound *X* relative to the reference gas CFC-11 is computed using the formula

$$ODP_X = \frac{m_{CFC11} \times \Delta\mu_{CFC11} \times \tau_X \times [\Delta O_3]_X}{m_X \times \Delta\mu_X \times \tau_{CFC11} \times [\Delta O_3]_{CFC11}}$$

where τ is the atmospheric lifetime, ΔO_3 is the change in globally averaged column ozone computed by the model, $\Delta\mu$ is the change in the mixing ratio boundary

condition, and m is the molecular weight of the ODS. The $\Delta\mu$'s should be small enough that the ozone change is linear in $\Delta\mu$.

In the ODP calculations we use the model calculated lifetimes for N₂O (98 years), CFC-11 (44 years), and CFC-12 (78 years) and the currently accepted value for HCFC-22 (12 years), whose loss is primarily due to reaction with tropospheric OH. (See below for a discussion of choice of lifetimes.) The perturbations used in the calculation are 100 pptv for the halocarbons and 50 ppbv for N₂O. All ODPs are computed with respect to ozone changes induced by CFC-11 at 2000 Cl_y levels and background aerosol loading. The calculated values are shown in Table SI-1.

SIT-1: ODPs vs. year of emission and aerosol level

	1959		2000	
	Background	Volcanic	Background	Volcanic
CFC-11	1.02	1.86	1.00 ¹	1.39
N ₂ O	0.026	0.019	0.017	0.009

¹All ODPs are referenced to ozone depletion by CFC-11 for background sulfate loading and Cl_y values in 2000.

The ODP of CFC-11 is nearly independent of Cl_y levels but does increase with volcanic loading, as expected, due to the greater activation of chlorine. N₂O, on the other hand, has a higher ODP when Cl_y levels are lower (55% larger for 1959 vs. 2000 Cl_y). The ODP of N₂O is also greatly reduced during times of high volcanic loading. All these changes are consistent with the anticipated roles of heterogeneous reactions on nitrogen and chlorine species and on the buffering effect between NO_x and chlorine radicals.

The vertical distribution of ozone depletion calculated by our model is shown in Fig. S1. The curves are in density units, rather than the percentage contributions that are often presented. To put these depletions in perspective, the right hand panel shows the global average ozone profile in this model. N₂O-induced ozone depletion maximizes in the middle stratosphere just above the ozone maximum while CFC-11-induced losses maximize in the lower stratosphere and upper stratosphere (the

upper stratospheric peak is more evident when viewed as a percentage change). In the lower stratosphere, there are ozone increases from N_2O increases due to enhanced UV radiation from the ozone decreases above. This “self-healing” effect is most important at tropical latitudes (not shown). Also, in the lower stratosphere at middle and high latitudes there are complex interactions between chlorine and nitrogen radicals and reservoirs that impact the ozone changes.

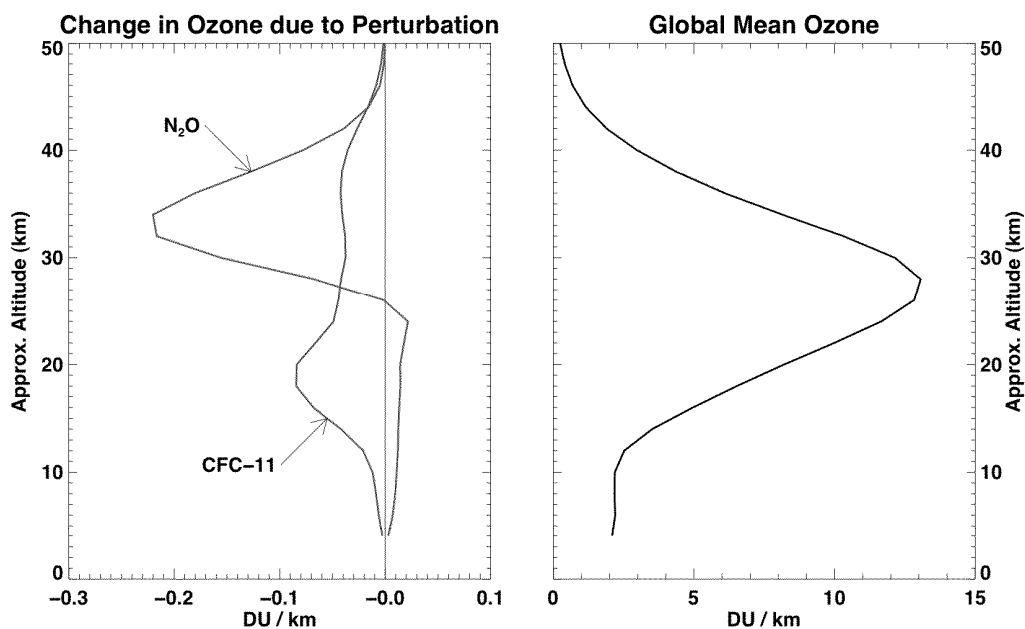


Fig. S1 The change in global average ozone due to a 100 pptv increase in CFC-11 and a 50 ppbv increase in N_2O for year 2000 levels of source gases and background aerosol conditions. The global average ozone profile for the same conditions is also shown.

Uncertainties in ODP estimate

Our calculated ODPs of CFC-12 and HCFC-22, using the same model as used for the N_2O calculation, agree well with the ODPs listed in the Montreal Protocol (1). Nevertheless, in addition to the uncertainties associated with the calculation of ODPs of chlorine-containing source gases, the N_2O ODP value does have important

and unique dependencies on sulfate and Cl_y levels. Because of the dependence on Cl_y levels, we have chosen to use the ODP calculated at today's levels in order to provide a conservative estimate of the future impact of N_2O on ozone. We also use the ODP for background aerosol conditions because of the temporary duration of elevated sulfate levels from volcanic eruptions.

N_2O , unlike Cl_y , does not cause enhanced ozone depletion in polar springtime (e.g., the ozone hole) and thus will not produce the extremely low ozone levels that enhanced Cl_y does. This spatial difference leads to a somewhat higher uncertainty in the ODP of N_2O than for chlorocarbon ODPs since there is less cancelation of errors in the calculated ozone depletion.

Inferred N_2O Emissions

We infer annual anthropogenic N_2O emissions from the highest and lowest mixing ratio projections of the A1B, A1T, A1FI, A2, and B1 SRES scenarios (2). We assume natural emissions account for 270 ppbv of atmospheric N_2O , the value observed during the preindustrial era (3), and that growth above that level is attributed to human activity. Total emissions are then inferred using a 1-box model and assuming an atmospheric lifetime of 125 years for N_2O (Volk et al., 1997) from the equation

$$E_{t-1} = \frac{\mu_t - \mu_{t-1} \exp\left(-\frac{1}{\tau_{\text{N}_2\text{O}}}\right)}{f \tau_{\text{N}_2\text{O}} \left(1 - \exp\left(-\frac{1}{\tau_{\text{N}_2\text{O}}}\right)\right)} \quad (\text{SOM 1})$$

where E_{t-1} is the emission in kg assumed constant throughout year $t-1$, μ_t is the N_2O mixing ratio at the beginning of year t , $\tau_{\text{N}_2\text{O}}$ is the lifetime of N_2O , and f relates the number of kg of N_2O to the number of ppb in the atmosphere (assumed to be 7.75×10^9 kg/ppb). A shorter lifetime would lead to larger emissions (see below). This method leads to total emissions slightly lower for the 1990s than suggested by IPCC (3) (16.0 vs. 17.7 TgN/yr) but in good agreement with those of Huang et al. (4)

and Hirsch et al. (5). Inferred anthropogenic emissions for the 1990s are also slightly lower than those of IPCC (3) (5.4 vs. 6.7 TgN/yr).

Comparison of influence of sectoral N₂O emissions with that of methyl bromide

One of the primary anthropogenic emissions of N₂O is associated with food production, where the agricultural practice of nitrogen fertilization leads to its emission. Therefore, it is interesting to compare the ODP-weighted emissions of N₂O from different sources with those of methyl bromide, which also has agricultural and food transport usage (Fig. S2). Clearly, N₂O emissions are much larger than those of methyl bromide. Indeed, most of the individual sectors of N₂O emissions are larger than the combined emissions of methyl bromide due to fumigation and use as feedstock.

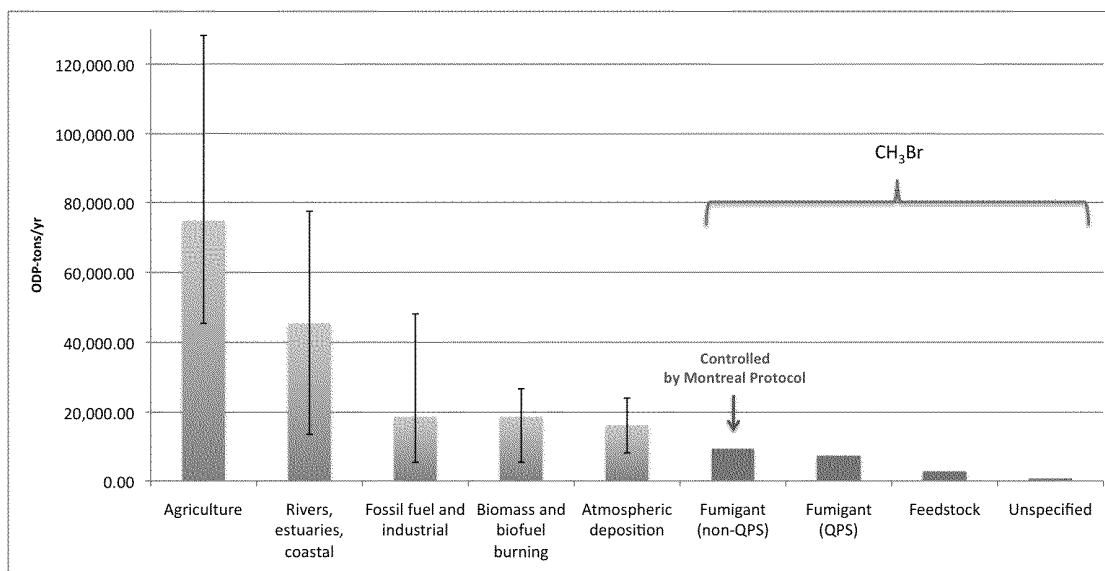


Fig. S2. Comparison of the ODP-weighted emissions of N₂O from various sectors with the ODP-weighted production of methyl bromide. The contribution of N₂O emissions from the agricultural sector far exceeds the contribution of methyl bromide. Indeed, most of the sectors of N₂O emissions outweigh the contribution of methyl bromide. Methyl bromide production estimates are for 2005 and are taken from UNEP MBTOC report (6); N₂O emissions come from IPCC report, Chapter 7 (7), and represent annual emission estimates for the 1990s.

Note on N₂O lifetimes

We use the 2D model-estimated lifetimes in the ODP calculations (e.g., 98 years for N₂O), and to infer N₂O emissions we use a lifetime value of 125 years, which is based on stratospheric observations (8) and has been used to infer N₂O emissions from a global network of observations (4). The shorter value in the ODP calculation was used to maximize internal consistency in the ODP estimate and the longer lifetime was used to estimate emissions in order to obtain conservative estimates.

From SOMF- 1 it is clear that an assumed shorter (longer) N₂O lifetime will lead to larger (smaller) inferred annual emissions. Therefore, by using an estimated lifetime that is somewhat higher than used in IPCC (3) and WMO/UNEP (9), we obtain annual emissions that are somewhat conservative. The lifetime used here is not an upper limit, however.

In the 2D model calculation there is, in general, a negative relationship between the lifetime for a gas and the steady state ozone depletion caused by an increase of that gas (this is a complex relationship and is dependent on the loss region for the gas being in stratosphere). Thus, when computing the ODP, it is preferable to use the model lifetime estimates even if they are somewhat different than the accepted values. IPCC 2007 (3) adopted a value of 114 years for the N₂O lifetime, about 14% larger than our model estimated value. Using the IPCC value would increase our ODP estimates by this same percentage. However, since the model lifetime for CFC-11 is likely too low by about the same fraction as the N₂O lifetime, there is a further cancelation of errors if the model lifetimes are used throughout as we have done.

Role of methane changes on ozone depletion

Several studies have shown that changes in methane in the 21st century will also affect the evolution of ozone (11). Methane's influence on ozone is very dependent on altitude. In the troposphere and lower stratosphere it induces ozone production via "smog chemistry" (10)), while at higher altitudes it causes ozone losses through

the HO_x radicals produced in its degradation to CO (and from the water produced as a byproduct). The net effect is generally a gain in column ozone due to methane increases, both in the stratospheric column and total column (11). Thus, unlike for N₂O, a calculated ODP for methane would likely be negative. Nevertheless, CH₄ should be considered when estimating the long-term changes in ozone. In addition to these effects of methane on ozone, there could also be a coupling between methane (and its breakdown products) and the effectiveness of NO_x on ozone destruction. These higher order effects could affect the ODP of N₂O during the 21st century. We have not estimated the magnitude of these effects but believe them to be small compared with the other uncertainties discussed in the paper (especially the emission estimates).

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Nitrous Oxide (N₂O): The Dominant Ozone-Depleting Substance Emitted in the 21st Century

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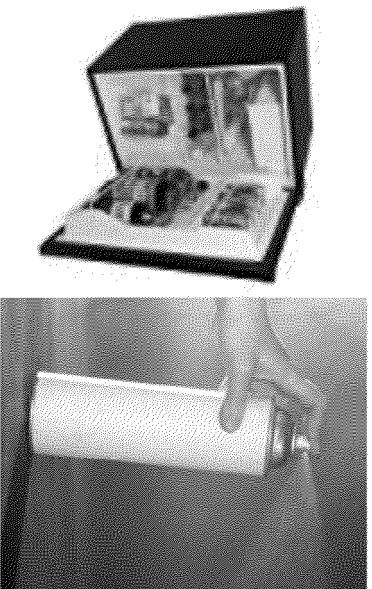
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Key Points of Presentation

1. Fact: NO_x from N_2O leads to ozone depletion; N_2O is not regulated under the Montreal Protocol.
2. In this paper: We have treated N_2O like any other ozone-depleting substance (CFCs, Halons, methyl bromide,...), and calculated its Ozone Depletion Potential (ODP).
3. In this paper: We used that ODP to compare the ODP-weighted emissions of **anthropogenic** N_2O to the ODP-weighted anthropogenic emissions of other ozone-depleting substances.
4. Finding: Anthropogenic N_2O is now the largest manmade ozone-depleting gas emission (a recent development owing to the successful abatement of CFCs and other ODSs under the Montreal Protocol!), and it will remain so for the next century if anthropogenic emissions of N_2O are unabated.

What we know: Chlorine catalyzes Ozone destruction

Gas phase homogeneous catalytic reactions that can destroy millions of times more ozone- small amounts can cause a big change



CFCs
(chlorofluorocarbons)

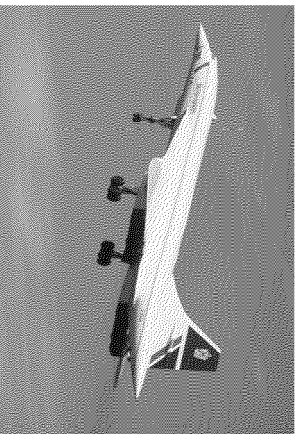


Molina and Rowland

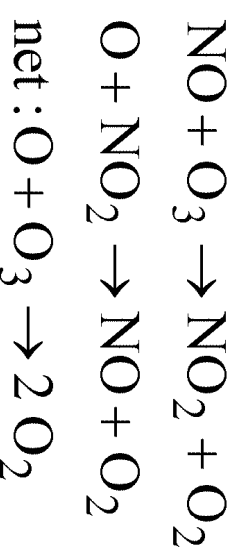
Findings from 2002 and 2006 SAP of UNEP/WMO:

- The Montreal Protocol is a success!
- The chlorine (and bromine) containing ODSs are decreasing in the atmosphere
- The ozone layer is expected to recover
- It is showing signs of recovery

What we know: NO_x also catalyzes ozone destruction

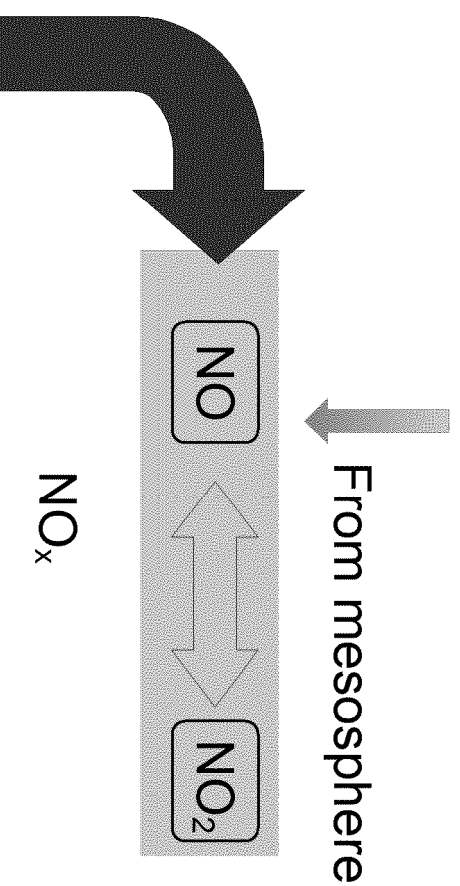


SSTs
NO/NO₂



- Additional catalytic cycles are also involved in O₃ destruction
- The NO_x cycle is a major ozone destroyer in the mid- to-upper stratosphere (part of the “natural” cycles?)
- Seminal work of Crutzen and Johnston ~ 40 years ago
 - nitrogen oxides cause ozone reductions.
- Nitrogen oxides from SSTs deplete ozone
 - the very first ozone layer depletion issue.

What we know: N_2O is the main source of stratospheric NO_x

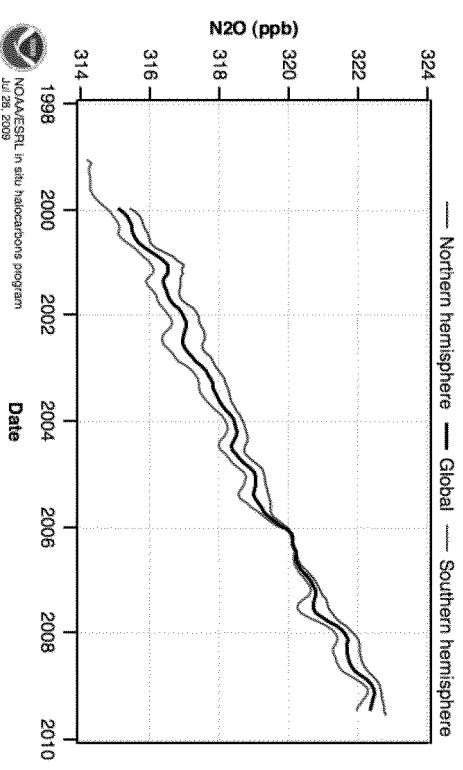
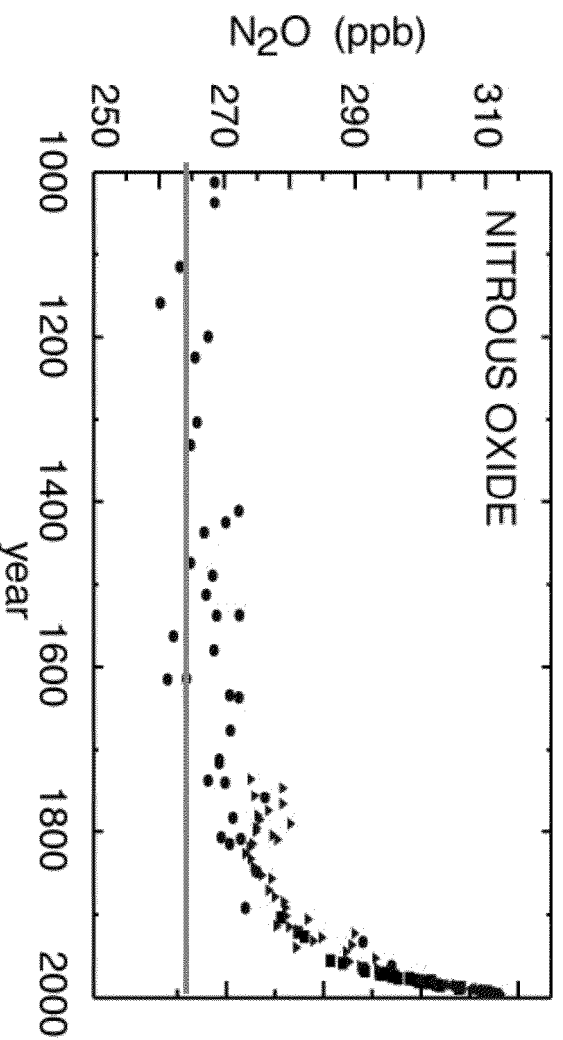


N_2O (from trop) N_2O is very stable in the troposphere

- ❑ As N_2O is converted to NO_x in the stratosphere
- ❑ ~10% of N_2O is converted to NO_y (NO_x)
- ❑ N_2O is the largest source of NO_x in the stratosphere

Many studies have examined what happens to the stratospheric ozone layer if nitrous oxide emissions are altered. Conclusion- Increasing N_2O leads to decreased in O_3 .

What we know: A significant part of N₂O emission is of human origin



- Preindustrial level ~270 parts per billion (ppb)
- Current level ~325 ppb
- Concentration continues to increase at roughly 0.25% (of total) per year; i.e., ~1% of anthropogenic component per year.
- All Increases in N₂O is due to anthropogenic activity—looks like other anthropogenic emissions, e.g., CO₂, CH₄
- Anthropogenic sources: agricultural fertilization, combustion, industrial production, etc.

What we did

Ozone Depletion Potential of N₂O

$$\text{ODP} = \frac{\text{Integrated Ozone depleted by emission of 1 kg of N}_2\text{O}}{\text{Integrated Ozone depleted by emission of 1 kg of CFC-11}}$$

Calculated ODP using Garcia-Solomon model for 2000 conditions

$$\text{ODP of N}_2\text{O} = 0.017$$

This **positive** number for ODP is comparable to those of some of the HCFCs:
HCFC-123 = 0.02; HCFC-124 = 0.022; HCFC-225ca = 0.025; HCFC-225cb = 0.033

N₂O is an ozone-depleting gas!

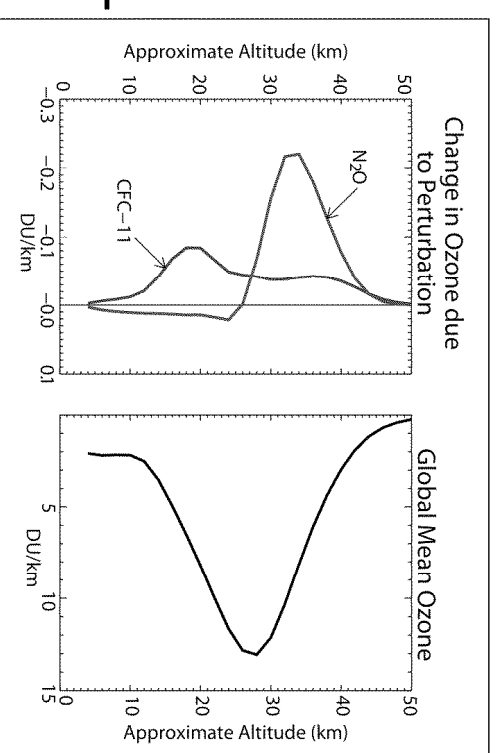
- Previous literature widely supports that N₂O destroys ozone
- To our knowledge, this is the first time N₂O is suggested to be an ozone-depleting substance in the same way that other gases that are already regulated under the Montreal Protocol

A few points about calculated ODP

Calculated ODP is robust

ODPs calculated in this study for CFC-12 is 1.03 and HCFC-22 is 0.06- agree with literature values.

O₃ depletion dominated by NO_x in mid-stratosphere, where 2D models do well



ODP influenced by chlorine amount in stratosphere

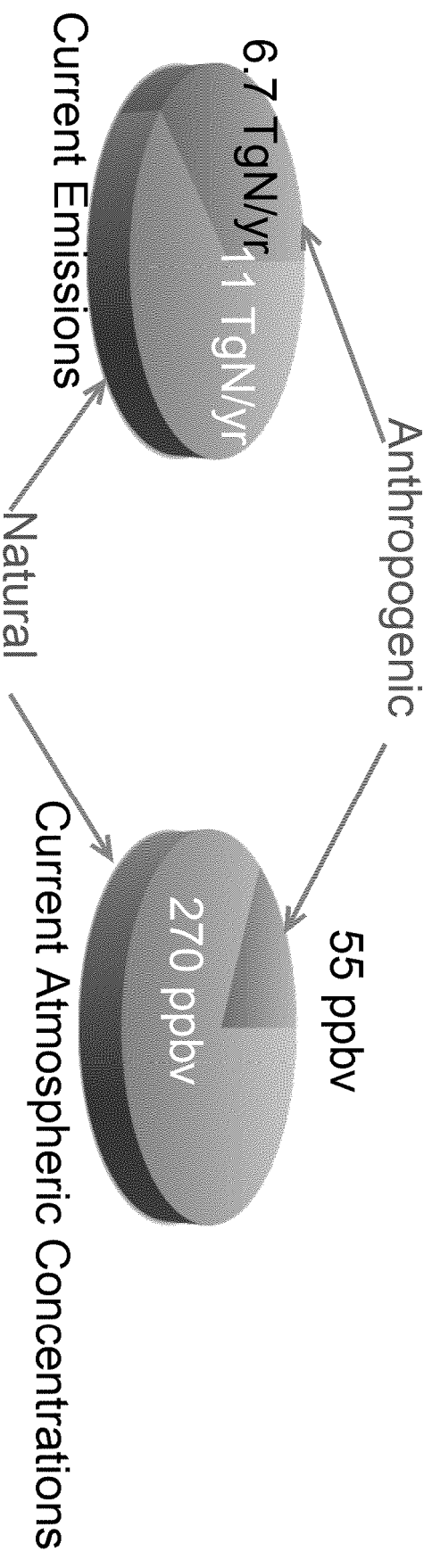
- ODP for 1959 levels of ODSs is 0.026

ODP is influenced by amount of sulfate aerosol in the stratosphere

-ODP for volcanic (like Mt. Pinatubo) conditions is 0.009 for 2000 and 0.019 for 1959; i.e., different ODPs for volcanic and non-volcanic periods

But, volcanic periods last only a couple of years

Implications of our findings



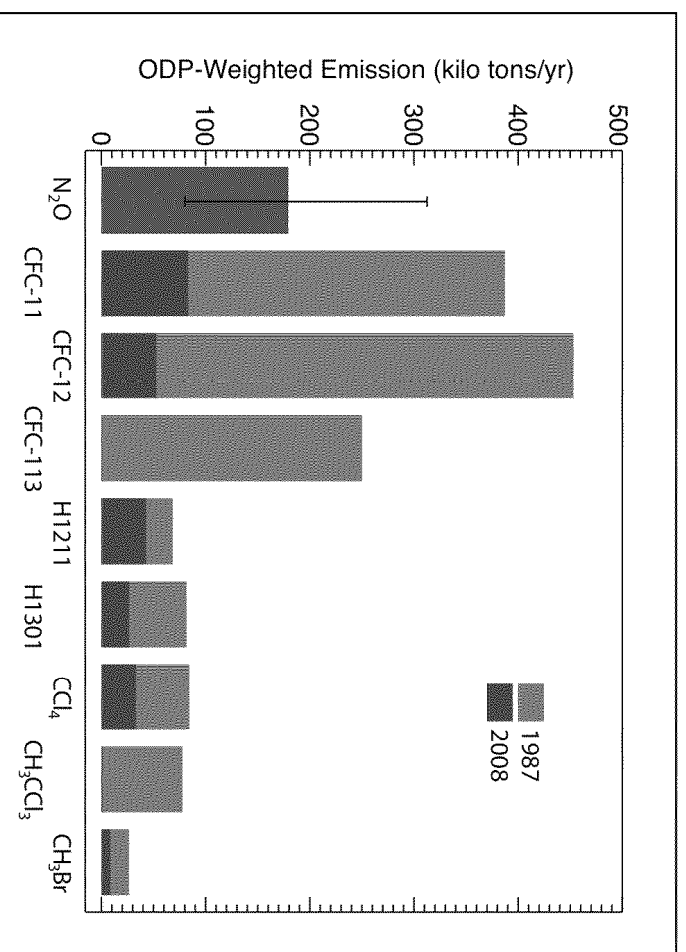
- ◆ Large Natural Emissions
- ◆ Even larger natural concentrations
- ◆ Anthropogenic concentrations growing rapidly

Two Key Points:

- Our discussion is restricted to anthropogenic emissions
 - the ones that are under human control
- N₂O's ODP is small
 - but its emissions are large

ODP alone does not tell the story

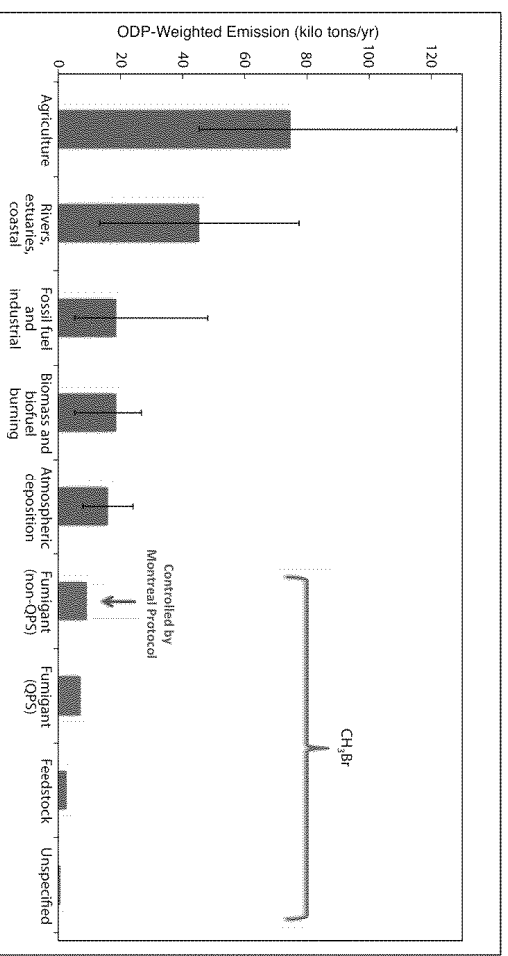
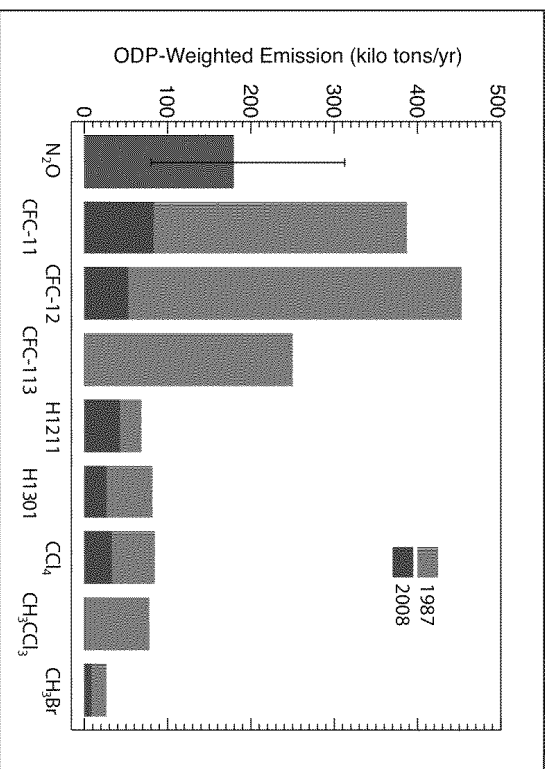
Compare the ODP-weighted anthropogenic N_2O emissions- not ODP-
with those of CFCs and other ozone-depleting substances



➤ Anthropogenic ODP-weighted-emissions of N_2O were the fourth largest ODS emissions even in 1987, at the height of the CFC emissions prior to the MP.

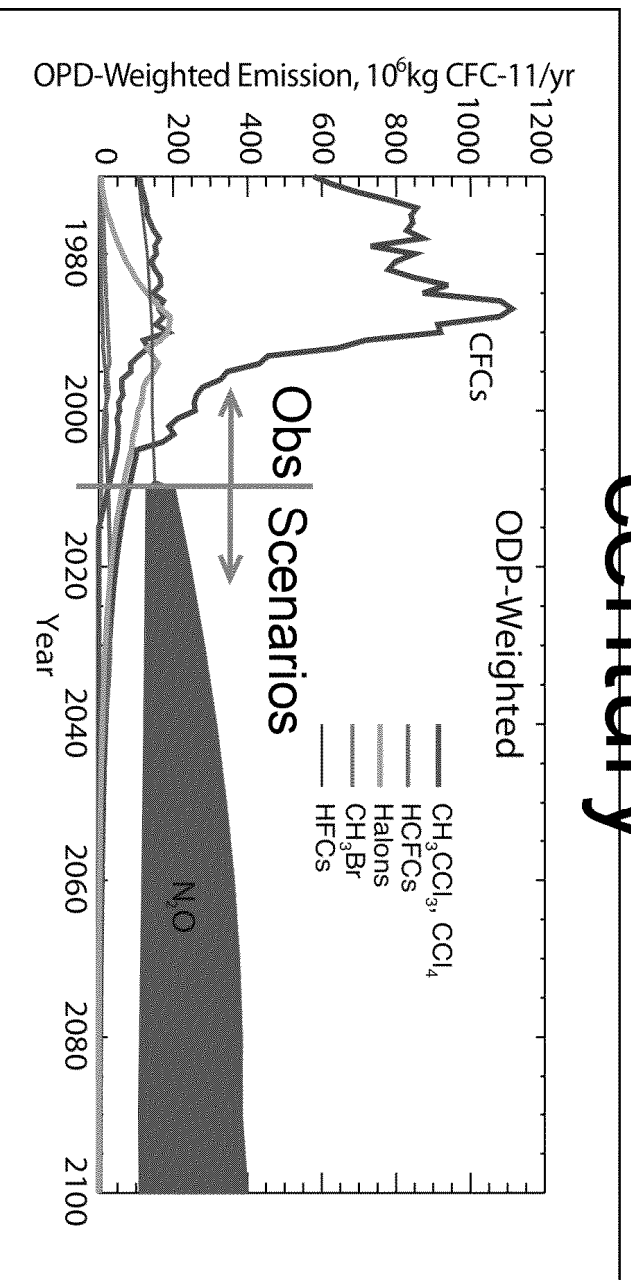
➤ Anthropogenic N_2O is now the largest ozone depletion gas emission; it will continue to be so and get even larger in the 21st century if the anthropogenic N_2O emissions are unabated

How does N₂O stack up against other emissions?



- Compares N₂O emissions contribution with some other ODS control strategies
- N₂O's contribution to ozone depletion is large compared to others when ODP-weighted emissions are used.
- Compare with methyl bromide- an emission related to agricultural and has both natural and anthropogenic origins
- The bank of CFCs is roughly equal to ~15 years of N₂O emissions

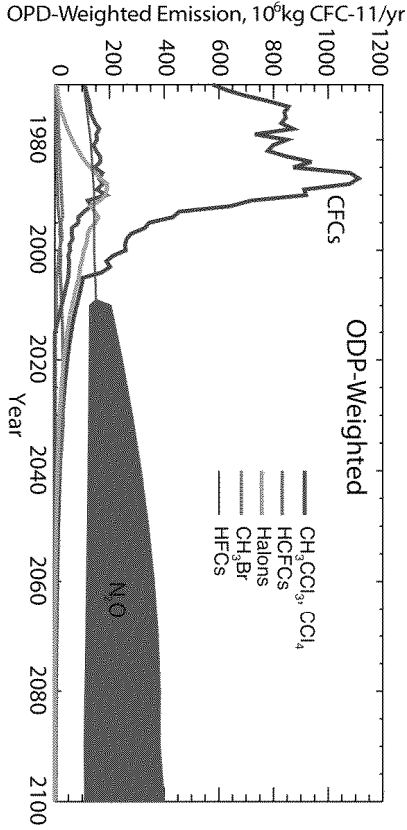
N₂O: the dominant ozone depleting substance emitted in the 21st century



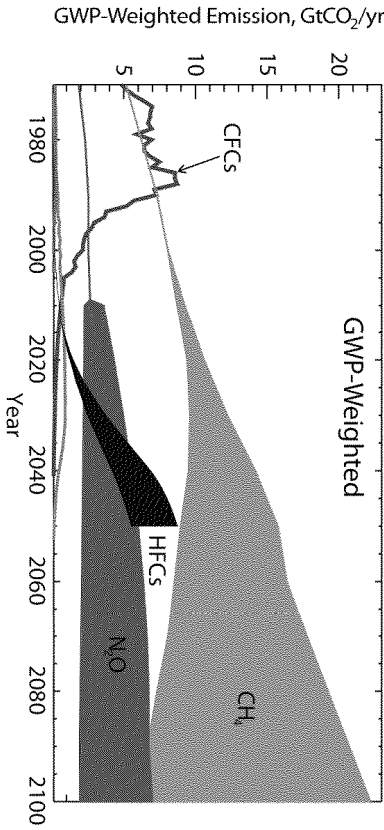
- N₂O is already the dominant ozone depleting substance being emitted today!
- Continued growth in N₂O, combined with decreasing chlorine loading, makes it even more important in the future.
- There are uncertainties in projections of N₂O growth- but even the most optimistic projections shows an increasing N₂O trend.

Climate benefits of reduced N₂O

Ozone depletion



Climate Forcing



There would be climate AND ozone layer benefits to reductions in N₂O emissions

— a “win-win” for both ozone and climate.

Differences between current ODSs and N₂O

- Chlorine and bromine containing ODSs induce ozone hole
- N₂O has negligible effect on ozone hole!
- Completely different chemistry- heterogeneous chemistry suppresses effects of N₂O in lower stratosphere and polar winter-spring stratosphere while het chem. enhances effects of chlorine.
- Different responses to volcanoes- chlorine induced ozone depletion increases, N₂O induced Nox effects decrease
- Differences in vertical regions of where these chemicals are active- with its implications to climate change and other changes
- Coupling with cycles different

Other issues

Changes in anthropogenic N₂O emissions will affect:

- (a) the estimated date for the recovery of the ozone layer;
- (b) imply that the use of a single parameter such as Equivalent Effective Stratospheric Chlorine, EESC, to estimate the recovery of the ozone layer should be reevaluated;
- (c) implications for the recovery of the polar ozone hole that might differ from that of global ozone;
- (d) Calls in to question the “baseline” for ozone recovery.

N₂O could be an unintended byproduct of enhanced crop growth for biofuel production or iron fertilization to mitigate CO₂ emissions. Such an enhancement would lead to the unintended ‘indirect’ consequence of ozone layer depletion and increased climate forcing from N₂O produced for alternative fuel used to curb global warming

For history: Ozone depletion by anthropogenic N₂O is roughly the same as that from the original projections for 500 US supersonic transport SSTs.

NO₂

II

ODS

Additional Slides

What we know: Others have studied the effect of N₂O increase

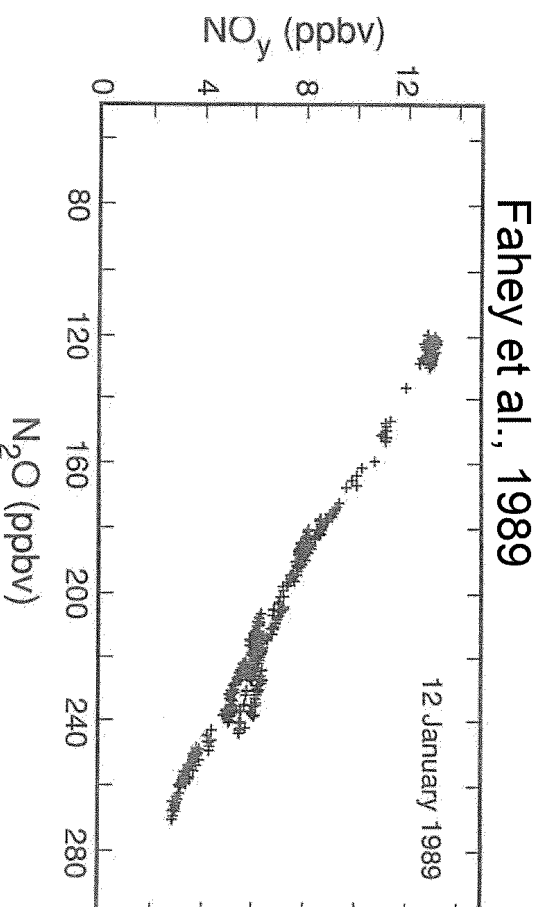
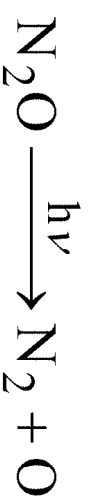
Many studies have examined what happens to the stratospheric ozone layer if nitrous oxide emissions are altered

Examples:

- Kinnison et al. (1988)
- Randeniya et al. (2002)
- Chipperfield and Feng (2003)

All indicate that ozone would decrease if N₂O increases

How is N₂O converted to NO_x?



To: Creason, Jared[Creason.Jared@epa.gov]; Wirth, Tom[Wirth.Tom@epa.gov]
From: Tubiello, Francesco (NRC)
Sent: Thur 7/11/2013 1:27:19 PM
Subject: RE: EPA Global Non-CO2 Mitigation Report expert review
Non-rice Croplands MAC_FNT.docx

Dear Jared,

Please find attached my comments to the report you sent me a few weeks ago. Apologies for a reply just at the end of the review period.

I thank you very much for considering me for this review.

I am afraid however you will not like my take on the work.

My major concern is that there is no attempt to quantify uncertainty in the study, whereas of course this must be significant, given the nature of the datasets required and the multiple assumptions that had to be made in order to arrive at a workable set of inputs at 0.5 degree, in order to be able to even run globally the model.

These fundamental uncertainties of course are compounded by those inherent in the model.

While I agree that such simulations need to be made, and they can do nothing but rely on the state of the art, I also think that they mostly belong to the realm of academia and associated speculations. When using them for publications by other bodies, especially for use by policy makers, it is a different matter. At the minimum, it is necessary and worthwhile, given the uncertainties at stake, to identify when and under which circumstances it is worthwhile to make them available and for what use.

In the spirit of regular international review systems of GHG inventories conducted under the UNFCCC, for instance, it is always good practice to also attempt a lower-level study using a tier 1 approach—as far as GHG data are concerned ---and see where that takes you, in order to be able to benchmark the higher tiered results and conduct proper QC/QA functions. We at FAO have produced tier 1 GHG numbers for all sectors in agriculture and lulucf and remain available should you desire to use them for such tasks.

For the mitigation potential, I think the options considered are too small a set, not appropriate for

many non-Annex I countries, and in general more limited in choice by the ability of the model than by a real search of what was possible in general. Specific options considered, especially the automatic fertilization, are a property of the model and do not have any correspondence to the world of a real farmer. Finally, it is very unclear how the critical economic numbers were derived.

All in all, even given the huge uncertainties, the study implies –at least it seems to me --that the carbon market is useless to agriculture when it comes to soil management in cropland, as most of the potential computed is at zero cost—which goes counter to what everyone seems to be saying. Nonetheless this is what the study appears to be saying, and it should be made explicit in the text.

Another sticky point for me is that a long set of critical input data used in the study is indicated as "FAO data," where in fact they are nothing of the sort. These data were produced in the course of a project-based contract between FAO and U Colorado, as far as I know, but were never published and are not available publicly at FAO in any shape or form. Hence it is ambiguous to indicate them as "FAO data" to the reader.

I remain available to contribute to any further discussion on this.

Best Regards,

Francesco

Francesco N. Tubiello

Natural Resources Officer, Project Coordinator

Monitoring and Assessment of GHG Emissions and Mitigation Potential in Agriculture

MICCA Programme

Climate, Energy and Tenure Division

Natural Resources Management and Environment Department

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<http://www.fao.org/climatechange/micca/ghg/en/>



From: Creason, Jared [mailto:Creason.Jared@epa.gov]
Sent: 08 July 2013 16:19
To: 'Francesco.Tubiello@fao.org'; Wirth, Tom; Helal.Ahammad@daff.gov.au; Wirth, Tom; ssmith@pnl.gov
Subject: FW: EPA Global Non-CO2 Mitigation Report expert review

Just a reminder that we need your comments! If you haven't had a chance to take a look at the draft EPA Global Non-CO2 Mitigation from Croplands technical document there is still time. . Please return written comments to me no later than 12 July, 2013. If you have questions, you can reach me anytime at creason.jared@epa.gov. I will respond and, if appropriate, share information with the other reviewers.

From: Creason, Jared
Sent: Friday, June 21, 2013 5:39 PM
To: Li, Jia; 'Smith Steven J (PNNL-JGCRI)'; 'Rose Steven'; 'Francesco.Tubiello@fao.org'; Wirth, Tom; Helal.Ahammad@daff.gov.au
Cc: Ragnauth, Shaun; Robert Beach; Ohrel, Sara
Subject: RE: EPA Global Non-CO2 Mitigation Report expert review

Attached please find the draft EPA Global Non-CO2 Mitigation from Croplands technical document for your review. This document is an update representing new analysis with the most recent version of the DAYCENT model. This effort , together with companion analysis of livestock and rice production, will form the basis of a chapter in EPA's new report "Global Mitigation of Non-CO2 Greenhouse Gases". (information available [here](#))

You are receiving this copy for review and comment. Please return written comments to me no later than 12 July, 2013. If you have questions, you can reach me anytime at creason.jared@epa.gov. I will respond and, if appropriate, share information with the other reviewers.

Your review of this short (~17 page) document is an important part of this overall effort and we appreciate your assistance!

Jared

Jared Creason, Ph.D.
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From: Creason, Jared
Sent: Tuesday, June 11, 2013 12:28 PM
To: Li, Jia; 'Smith Steven J (PNNL-JGCRI)'; 'Rose Steven'; Helal.Ahammad@daff.gov.au;
'Francesco.Tubiello@fao.org'; Wirth, Tom
Cc: Ragnauth, Shaun; Robert Beach
Subject: RE: EPA Global Non-CO2 Mitigation Report peer review

First, I want to apologize for the long delay since Jia's last communication about the status of the croplands MAC analysis. As she indicated, some issues were discovered within the DAYCENT modeling. These issues have been corrected and this most recent DAYCENT model was used to estimate the croplands emissions reported in the Inventory of U.S. GHG Emissions and Sinks ([available here](#))

Currently, we are updating the croplands MAC technical document with global results from this

most recent DAYCENT model and will soon have a technical document for review. I'm writing today to ask if you are still willing to serve as an expert reviewer of this document. Please let me know about your near-term availability. I'm hoping to get the document to you by June 21 and would look for your response by July 12. Does that seem like something you could do?

Thank you for your continued support and we look forward to working with you soon.

Expert Review Technical Document

Global Mitigation of Non-CO₂ Greenhouse Gases: Non-Rice Cropland Soil Management

The U.S. Environmental Protection Agency (EPA)'s Office of Atmospheric Programs, Climate Change Division is currently updating its 2006 report, *Global Mitigation of Non-CO₂ Greenhouse Gases* (USEPA, 2006). The updated report will include a chapter on non-CO₂ greenhouse gas (GHG) mitigation marginal abatement cost (MAC) curve analysis for agriculture that focuses on three agricultural subsectors: rice cultivation, non-rice cropland soil management and livestock management. This document describes the methods, data and assumptions used to develop the MAC curve analysis for global non-rice cropland soil management, and highlights key results. The current results included in this draft for expert review should be considered preliminary.

1. Introduction

The agricultural sector is the largest source of global non-CO₂ GHG emissions. According to the *Global Anthropogenic Non-CO₂ Greenhouse Gas Emissions: 1990-2030* (USEPA, 2012), in 2005 the sector contributed to 54 percent of the global total non-CO₂ emissions, 82 percent of the global nitrous oxide (N₂O) emissions, and 45 percent of the global methane (CH₄) emissions. Global non-CO₂ emissions from agricultural sources are projected to increase in coming decades, particularly in the developing countries, due to growing populations and higher global incomes. Agricultural non-CO₂ emissions mainly come from four sources: 1) cropland soil management (primarily N₂O), 2) rice cultivation (CH₄ and N₂O, with CH₄ from flooded rice paddies dominating), 3) ruminant livestock enteric fermentation (CH₄), and 4) livestock manure management (both CH₄ and N₂O, with CH₄ from anaerobic manure management systems dominating). In addition to non-CO₂ GHG emissions, changes in soil carbon are also important determinants of net GHG emissions for soil management and rice cultivation.

Numerous mitigation options for agricultural GHG emissions can be readily identified. However, assessment of agricultural mitigation options remains challenging, as the sector is highly dispersed and spatially heterogeneous, not only from region to region, but from farm to farm. Its emissions are also highly variable and not directly monitored, which poses significant uncertainty in quantifying emissions and changes in emissions due to mitigation activities. The lack of regionally specific cost data for implementing mitigation options further complicates analysis of cost-effective mitigation opportunities in this sector.

USEPA (2006) is one of the few studies to explore agricultural non-CO₂ mitigation potential and costs globally. The forthcoming report will update the data, methods, and parameters in the USEPA (2006) study to provide more detailed, geographically disaggregated, and updated MAC curves for global GHG emissions from agriculture.

2. Background on N₂O and CH₄ Emissions and Changes in Soil Carbon from Non-Rice Cropland Soils

Land management in croplands influences soil N₂O emissions, CH₄ fluxes, and soil organic carbon (C) stocks (and associated CO₂ fluxes to the atmosphere). Soil N₂O emissions are influenced by human activity, including synthetic nitrogen fertilization practices, application of organic fertilizers such as manure, drainage of organic soils, cultivation of N-fixing crops, and enhancement of N mineralization in soils through practices such as nitrogen applications for cultivation of native grasslands and forest management (Mosier et al., 1998; Smith et al., 2007). N₂O emissions from agricultural soils increased by about 19%, from 1,658 to 1,969 MtCO₂e between 1990 and 2010 (USEPA, 2012). In 2010, soil N₂O emissions account for approximately 56% of the global agricultural N₂O emissions, up from 51 percent in 1990 (USEPA, 2012). CH₄ is typically a minor flux in non-rice croplands soils, but we account for any changes in CH₄ as part of our net GHG calculations to ensure a more complete accounting for GHG emissions.

In contrast to soil N₂O, where there are sizable annual fluxes that depend on human activity, soil organic C stocks are assumed to be approximately in equilibrium, except of drained organic soils. Major changes in soil C occurred when land was first cultivated, but changes associated with agricultural soil management are approximately balanced at a global scale based on current management and land use change trends (Smith et al., 2007). Although soil organic C stock fluxes are negligible in the baseline, there is considerable opportunity to modify stocks in the future. Levels of soil organic matter and in particular soil carbon both influence, and are influenced by cropland productivity – Other things being equal, higher crop yields may increase soil C wherever more crop residue can be incorporated into the soil. Therefore, many management techniques intended to increase production may potentially increase soil organic matter, thus sequestering atmospheric carbon. Smith et al. (2007) estimated that 89% of the overall technical potential for mitigation of agricultural greenhouse gas emissions is associated with carbon sequestration in soils. Practices such as adoption of conservation tillage, restoration of degraded lands, improved water and nutrient management, and cropping intensification can increase soil carbon by enhancing C inputs to soils from greater crop production or decrease the losses of C from soils with lower decomposition rates (Paustian et al. 1997).

3. Methods

3.1 DAYCENT Modeling of GHG Fluxes and Crop Yields

The DAYCENT ecosystem model was used to estimate crop yields, N₂O and CH₄ emissions, and soil C stocks in this analysis. DAYCENT is a process-based model (Parton et al., 1998; Del Grosso et al., 2001) that simulates biogeochemical C and N fluxes between the atmosphere, vegetation, and soil by representing the influence of environmental conditions on these fluxes including soil characteristics and weather patterns, crop and forage qualities, and management practices. DAYCENT utilizes the soil C modeling framework developed in Century model (Parton et al. 1987, 1988, 1994; Metherell et al. 1993), with refinement to simulate C dynamics at a daily time-step. Key processes simulated by DAYCENT include crop production, organic matter formation and decomposition, soil water and temperature regimes by layer, in addition to

nitrification and denitrification processes. DAYCENT has been evaluated in several studies (e.g., Del Grosso et al. 2002, 2005, 2009) and is also used by EPA to develop the annual Inventory of U.S. Greenhouse Gas Emissions and Sinks in agriculture (EPA, 2013).

Crop yields, direct N₂O and CH₄ emissions, and soil organic C stock changes were simulated by DAYCENT at a 0.5 degree grid resolution. Indirect N₂O emissions¹ were estimated using the IPCC default factors for indirect N₂O emissions (De Klein et al., 2006), and using simulated amounts of nitrate leaching, N runoff in overland water flow, and NO_x emissions from a site according to the DAYCENT model². In order to represent the longer term effect of cultivation on soil C, simulations started in 1700 after a simulation of 3000 years of native vegetation, which is a similar procedure to the methods applied in the US Greenhouse Gas Inventory for agricultural soil C (USEPA, 2013).

3.1.1 DAYCENT Model Inputs

For this study, a number of data sources were used to establish the business-as-usual baseline conditions and simulate alternative management options for the global non-rice croplands. Weather data were based on a dataset generated by the North American Carbon Program at a 0.5 degree resolution, with daily minimum and maximum temperatures and daily precipitation.³ The soils data were based on the FAO Digitized Soil Map of the World (FAO 1996). Major cropland areas of the world were simulated according to a global cropland map developed by Ramankutty et al. (2008), with grid cells with less than 5% cropland area excluded in the analysis.

Native vegetation data are described in Cramer and Field (1999) and Melillo et al. (1993). The approximate first year of cultivation was based on historical records compiled by Ramankutty and Foley (1999) and Ramankutty et al. (2008).

Low input crop production with intensive tillage practices were assumed prior to 1950. From 1950 to 2010, management was based on FAO data (THIS IS TOTALLY INAPPROPRIATE AND INCORRECT AS A STATEMENT. SEE COMMENTS AT THE END IN THE APPENDIX, including tillage and residue management, weeding practices, mineral N fertilization, manure N amendments to soils, and irrigation. Table 1 provides summary statistics of the baseline management practices at regional level for the five crops (maize, wheat, barley, sorghum and soybean) simulated in DAYCENT. Crop planting and harvest dates were based on Sacks et al. (2008). Crops were assumed to grow in monoculture due to insufficient data for determining typical crop rotation practices from the global datasets. Future analyses could improve upon this research if realistic crop rotations are developed. Maize and sorghum were double-cropped in some regions based on Sacks et al. (2008). Model performance was evaluated by comparing simulated crop yields to observed crop yields (Monfreda et al. 2008), and minor adjustments were made to parameters in order to be reasonably consistent with the observed yields. More detail on the input data and simulation framework is provided in Appendix A.

¹ N₂O emissions occurring with transport of N from one site to another where N₂O emissions occur with N addition.

² The same method as used in the US National Greenhouse Gas Inventory (USEPA, 2013).

³ The Multi-Scale Synthesis and Terrestrial Model Intercomparison Project (MsTMIP) developed consistent weather data in order to “isolate, interpret, and address differences in process parameterizations among [terrestrial biospheric models]” Source: <http://nacp.ornl.gov/MsTMIP.shtml>.

Table 1. Baseline practices for the non-rice cropland simulations using DAYCENT model¹

Region	Crop	N application rate 2011 – 2035 (g N m ⁻² yr ⁻¹)	Percent of cropland using full inversion tillage (%) ²	Percent of cropland in irrigation (%)	Mean crop residue removal rate (%)
Africa	barley	2.74	100	6.3	43.6
	maize	6.72	100	6.0	62.9
	sorghu m	2.09	100	2.2	40.9
	soybean	1.51	100	4.3	33.9
	wheat	6.92	100	21.1	47.6
Asia	barley	8.91	100	24.6	53.4
	maize	13.08	100	30.7	57.5
	sorghu m	9.33	100	39.3	40.9
	soybean	5.46	100	23.1	33.9
	wheat	15.24	100	51.4	52.3
Central & South America	barley	7.45	100	14.6	40.0
	maize	6.09	100	8.5	40.0
	sorghu m	6.01	100	6.9	40.0
	soybean	0.36	100	2.2	40.0
	wheat	5.59	100	9.0	40.0
Eurasia	barley	2.65	100	6.8	40.1
	maize	5.56	100	17.8	40.1
	sorghu m	4.16	100	34.9	43.3
	soybean	0.85	100	3.8	40.2
	wheat	0.09	100	8.7	40.1
Europe	barley	8.11	100	8.3	40.0
	maize	11.55	100	47.6	40.0
	sorghu m	3.63	100	25.2	40.0
	soybean	4.65	100	45.1	40.0
	wheat	10.34	100	6.6	40.0
Middle East	barley	8.84	100	44.0	39.8
	maize	24.54	100	55.3	39.7
	sorghu m	6.43	100	7.6	40.0
	soybean	5.78	100	38.7	40.3
	wheat	5.69	100	44.6	39.8
North America	barley	5.72	100	24.4	33.7
	maize	14.94	100	34.3	25.9
	sorghu m	8.87	100	39.8	25.3
	soybean	4.13	100	19.1	23.8
	wheat	7.49	100	26.4	29.0

Notes: 1.The numerical values represent averages for all grid cells in a region. 2. The analysis currently assumes 100% conventional tillage of the croplands covered in the analysis. Alternative representation of baseline tillage practices are being investigated for different regions based on the available data thus estimated changes between the baseline and “no till” scenario may change.

Please put a section here on uncertainties. I understand this is a tier 3 methodology as per IPCC guidelines. Except

that the hundreds of assumptions made here, not to mention simulation run design and intrinsic model uncertainty, appear to likely results in estimates that are far more uncertain than by using a straight tier 1 approach. Please comment.

3.1.2 Simulations

Global DAYCENT modeling was carried out for irrigated and non-irrigated production systems for maize, wheat, barley, soybean and sorghum. Crop yields and GHG fluxes were simulated at the 0.5 degree resolution for periods 2000-2010 and 2011-2030 with five-year increments. A baseline scenario is established for each crop production system assuming business-as-usual management practices described above. Seven mitigation scenarios were then analyzed (see Section 3.4 below).

In most regions, the simulated cropland areas for each crop in DAYCENT, based on Monfreda et al. (2008), are lower than the harvest areas reported in FAOSTAT. We performed two adjustments to the Monfreda et al cropland areas in order to improve the mitigation estimates. First, the simulated cropland areas were scaled to match FAOSTAT harvest areas. Second, analogous crops were added to these major crop types (i.e., oats with wheat, rye with barley, green corn with maize, and lentil, green bean, string bean, broad bean, cow pea, chickpea and dry bean with soybeans) to increase the coverage of cropland area and to capture a higher portion of nitrogen fertilizer applications. With these adjustments, the cropland area simulated in DAYCENT increased from approximately 40% of the global croplands (excluding rice cultivation) to about 61% of the global non-rice cropland areas reported by FAOSTAT. This coverage adequately represents most of the croplands and practices responsible for GHG emissions. Rangeland is not included and emissions from burning residue are not included.

Projected baseline emissions and crop production were then established for both irrigated and rainfed production systems using simulated yields and GHG emissions rates from DAYCENT model and adjusting with projected growth rates of these production systems by the International Food Policy Research Institute (IFPRI)'s International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT) model. In DAYCENT, crop production areas were held constant at the 2010 level to obtain the biophysical effects of management practice changes on crop yields and GHG fluxes. Projected acreage changes from IMPACT model reflect socio-economic drivers such as population growth and technological changes to meet the global food demand (Nelson et al., 2010).

Figure 1 presents projected baseline N₂O and CH₄ emissions and changes in soil organic carbon from non-rice cropland soils; As shown in Figure 1, N₂O emissions from global non-rice cropland soils are projected to be 506, 500 and 504 million metric tons of CO₂ equivalent (MtCO₂e) in 2010, 2020 and 2030, respectively.⁴ Non-rice cropland soils are a net sink for methane, sequestering approximately 38 MtCO₂e of CH₄ per year. The estimated net changes in soil organic carbon suggest that the carbon stock changes are roughly balanced at the global scale.

⁴ The relatively constant GHG emissions projected in the baseline are mainly driven by the DAYCENT modeling that assumes the same management practices are applied throughout the study period as well as relatively small changes in cropland areas in the IMPACT model projections (FNT but it is stated above that changes in land area were not considered). Estimated emissions of one mitigation option "auto-fertilization," which allows optimal N fertilizer applications to enhance crop yields discussed in Section 3.4, would provide insights on the potential implications of production intensification on GHG emissions.

Figure 2 presents the projected net GHG emissions (N_2O and CH_4) from the top-five emitting countries. The top 5 countries of China, India, the United States, Brazil and Argentina represent about 63% of global net emissions from cropland in 2010.

Figure 1. Baseline Emissions Projections for N_2O , CH_4 and Changes in Soil Organic Carbon from Global Non-Rice Cropland Soils

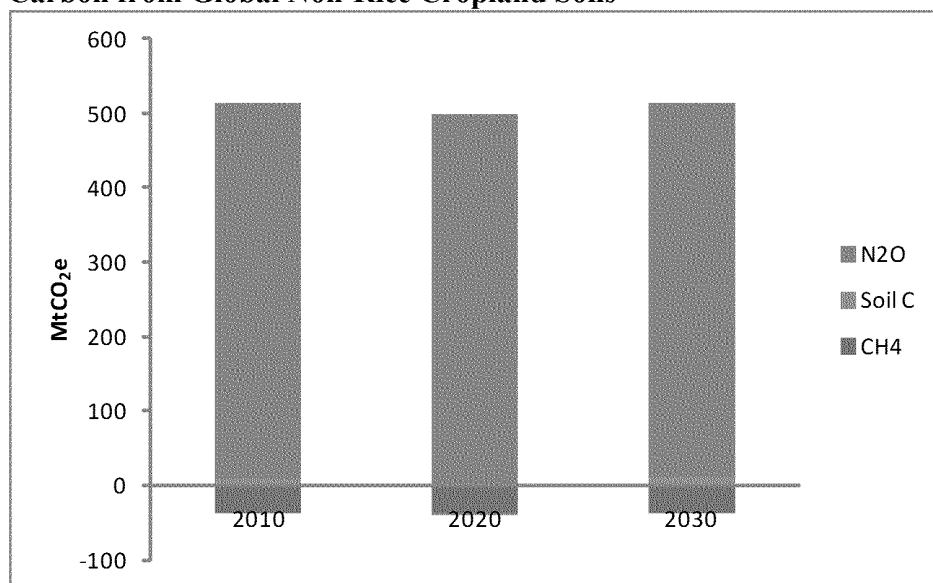
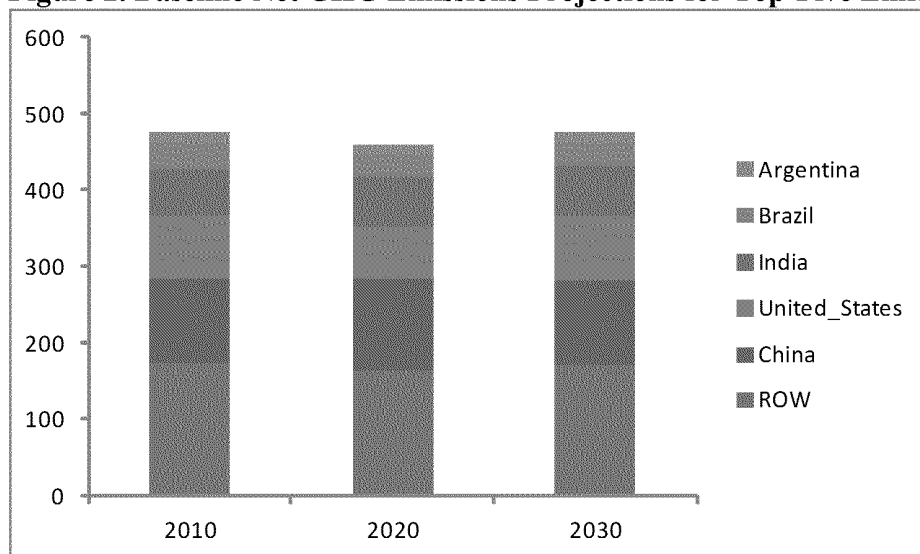


Figure 2. Baseline Net GHG Emissions Projections for Top-Five Emitting Countries



Note: ROW = rest of the world.

3.2 General Framework to Estimate Total Emission Reductions

To develop MAC curves, a set of mitigation options identified in the literature were analyzed for each agricultural subsector. Emissions, yields, productivity changes, labor requirement and other factors from the mitigation scenarios were compared with baseline conditions for the years 2010, 2020, and 2030, and for all agricultural regions throughout the world. This framework is a bottom-up engineering cost approach, where individual mitigation studies from one region are assumed to be representative of that region, and are then extrapolated to other regions of the world, adjusting for regional cost and revenue differences, as well as regional activity data. If a mitigation option is considered technically feasible for a given region, it is assumed to be adopted immediately, i.e., in 2010, and the change in management is continuous for the entire study period. Mitigation estimates therefore represent the technical potential for GHG reductions, without accounting for implementation barriers that may slow adoption of technically feasible options.

Table 2 below lists the key parameters and assumptions used to calculate the emission reduction (ER) for each mitigation option in each region.

Table 2. Characterization of Mitigation Options in General Framework

Characteristic	Unit	Definition
Availability (A)	Yes/No	Projected availability of a specific option in a given region and year.
Technical Applicability (TA)	(1) Percent (%)	% of baseline emissions to which a given option can be applied.
	(2) unitless	Include only activity data to which mitigation option applies.
Economic Applicability (EA)	Percent (%)	Remaining emissions (baseline * TA) segmented by $1/n$ where n = number of mitigation options, to avoid overlapping options.
Reduction Efficiency (RE)	(1) Percent (%)	% of remaining emissions (baseline * TA * EA) reduced when mitigation option is applied, taken directly from literature.
Lifetime (L)	Years	Average technical lifetime of an option or the capital equipment used in an option.
Abatement Potential (AP)	Percent (%)	% (TA * EA * RE) of baseline emissions reduced by option.
Emission Reduction (ER)	MtCO ₂ e	(1) Absolute amount of baseline emissions reduced by an option per year (baseline * AP).

(1) Literature gives % emission reduction when mitigation option is applied.

(2) Literature gives activity data from which emission reduction is derived.

The first parameter defined for each mitigation option is availability (A). If an option was determined not to be available in a given region, no further analysis was done for that option in

that region throughout the analysis period. Because the mitigation options included in the analysis were typically analyzed for particular countries or regions in the literature, expert judgment is used to determine whether those same mitigation options are available in other countries.

Two similar approaches are employed to define technical applicability (TA), depending on the underlying data available to characterize the quantity of GHG emissions to which the mitigation options can be applied. In the first approach, TA is estimated to be the percentage of baseline emissions to which the mitigation option could apply (e.g., the percentage of baseline manure CH₄ emissions to which a centralized digester could apply). In the second approach, TA is addressed by only including those activity data to which mitigation options apply.

Economic applicability (EA) of the mitigation option is assumed to be the percentage of baseline emissions (baseline * TA) to which an option could apply, taking into account economic and infrastructure factors and barriers. EA is $1/n$ where n is the number of mitigation options. This assumes all mitigation options are applicable to a uniform segmentation of baseline emissions, notwithstanding their net costs and benefits. Each set of mitigation options for each emission category in each region was assumed to be implemented simultaneously, but without any overlap among the options. This is a simplistic method that avoids double-counting among options but likely underestimates potential penetration of low-cost options and overestimates potential penetration of high-cost options.

Reduction efficiency (RE) refers to the percentage of baseline emissions reduced after the mitigation option has been applied, which, in the first approach, is taken directly from the literature. In the second approach, RE is the reduction in appropriate activity data.

The total emission reduction (ER) is the absolute magnitude of mitigation, expressed as million metric tons of carbon dioxide equivalent (MtCO₂e).⁵ It is calculated as the product of the abatement potential percentage (TA * EA * RE) and baseline emissions. For cropland cultivation, estimated total emission reductions not only account for total non-CO₂ emissions (i.e., N₂O) but also changes in soil organic C stock, thus are the *net* GHG emission reductions.

3.3 Estimating Costs to Establish Marginal Abatement Curves

As a general framework of the MAC analysis, the break-even price for each mitigation option is calculated by setting total benefits (e.g., higher yields, coproducts) equal to total costs of a given mitigation option. This framework, also referred to as the International Marginal Abatement Cost (IMAC) model, is documented in USEPA (2006) and Beach et al. (2008). Total emission reductions, estimated through the general approach described above, and other parameters are fed into the equation below to determine the present value break-even mitigation cost (P), in 2010 USD, per unit emission reduction in a given region, expressed as \$/tCO₂e. The analysis solves for P:

⁵ We use 100-year global warming potentials (GWPs) from IPCC's Second Assessment Report to convert N₂O (GWP = 310) and CH₄ (GWP = 21) to CO₂ eq (Schimel et al., 1996), to be consistent with current UNFCCC emissions inventory reporting guidelines.

PV (Benefits) = PV (Costs) or more specifically,

$$\sum_{t=1}^T \left[\frac{(PxER) + R + TB}{(1 + DR)^t} \right] = CC + \sum_{t=1}^T \left[\frac{(RC)}{(1 + DR)^t} \right]$$

where: PV = present value

P = break-even price of the option in \$/tCO₂e (in 2010 USD)

ER = absolute emission reduction achieved by the option (see Table 1 above)

R = revenue changes due to mitigation option (e.g., yields, electricity generation).

T = option lifetime

DR = selected discount rate (10% for these estimates)

CC = capital cost of the option (fixed across regions; only applicable for manure options)

RC = recurring O&M cost of the option (scaled based on regional agricultural wages)

TB = tax credits equal to CC/T * TR (TR = 40%), applied only to manure CH₄ options

Costs include capital costs (CC), recurring operation and maintenance (O&M) costs (RC) for capital equipment, and changes in input usage and costs (e.g., labor). Capital costs remain fixed across regions (and only occur in manure CH₄ mitigation options), whereas O&M costs are scaled according to different labor ratios using available data on agricultural wages provided by the IFPRI. TB represents reduced tax associated with capital purchases, using a 40% tax rate. The cost assumptions for each mitigation option are provided in data annex “Non-Rice Croplands MAC Results and Assumptions.”

Positive and negative effects on revenues are also calculated. Revenue effects include changes in crop production per acre as yields change. More detail on how the costs and benefits were determined for each mitigation option is given below.

3.4 Selected Mitigation Options

The mitigation options evaluated in this analysis were based on review of the literature to identify the most promising options, while also taking data availability and potential for modeling within DAYCENT into consideration. The mitigation options represent alternative management practices that would alter crop yields and the associated GHG emissions, including optimal N fertilization to enhance crop yields, split N fertilization applications, application of nitrification inhibitors, increased N fertilization (20% increase over business-as-usual), decreased N fertilization (20% reduction from business-as-usual), 100% crop residue incorporation, and adoption of no-till management (see Table 3 for descriptions of the mitigation measures). More detailed description of the assumptions used for each of the mitigation options is provided in the data annex “Non-Rice Croplands MAC Results and Assumptions.”

The N management practices (optimal fertilization, split N fertilization, nitrification inhibitors, increased and decreased N fertilization) influence N₂O emissions in addition to soil organic C stocks due to reduced or enhanced C inputs associated with the level of crop production. Similarly, reducing crop residue removal would impact soil organic C stocks by changing the

amount of C input to the soil. No-till also has an influence on crop production and C inputs (Ogle et al., 2012), but can also reduce C losses due to protection of C from microbial decomposition in soil micro-aggregates (Six et al. 2000).

In addition, irrigation is also considered as a potential strategy to enhance crop yields and reduce GHG emissions intensity. The results presented in this document do not include this option. However, irrigation will be explored and possibly be included in the final report.

Table 3. Alternative Management Scenarios Simulated in the DAYCENT Model

Mitigation option	Description
Optimal N fertilization (“Auto-fertilization”)	Optimal N fertilization application rates were computed by the model. The model applies an auto-fertilization routine that removes nutrient stress and increases nutrient content by 25% above minimum level. N was added to the soil daily from date of planting to date of harvest.
Split N fertilization	The baseline N application amount was applied in three separate and equal amounts (planting day, 16 days after planting day, and 47 days after planting day) instead of once on planting day.
Nitrification inhibitors	The baseline N application amount was applied once annually on date of planting. Nitrification inhibitors were applied at time of fertilization, and reduced nitrification by 50% for 8 weeks.
Reduced N fertilization application	Annual N applications amounts were reduced by 20% relative to the baseline.
Increased N fertilization application	Annual N application amounts were increased by 20% relative to the baseline (maize, spring and winter wheat, spring and winter barley, and sorghum only; this option was not simulated for soybeans or millet)
100% residue incorporation	There was no crop residue removal after grain harvest to evaluate how increasing removals would impact soil organic C stocks.
No till adoption	All cultivation and field preparation events were removed except for seeding, which occurred directly into the residue.

4. Mitigation Results

Figure 3 presents the MAC curves for the global non-rice croplands, in 2010, 2020 and 2030. The non-rice croplands MAC curves presented in this chapter are distinctive because they show less abatement potential in 2030 than in 2010 – the 2030 curve is to the left or “inside” the 2020 and 2010 curves. This is due to the effect of soils becoming “saturated” as they move towards a new equilibrium. Although it takes a few decades to fully reach a new equilibrium in the model, much of the adjustment takes place within the first 10-15 years of a management change.

MAC analysis of the mitigation options described above suggests that at no or a relatively low carbon price of \$5 per ton of CO₂ equivalent (\$/tCO₂e), net GHG abatement potential for global non-rice cropland soils is approximately 111 MtCO₂e, or about 23% of its baseline net emissions of 476 MtCO₂e in 2010. Mitigation potential at \$5/ tCO₂e reduces to 17% of the sector’s baseline emissions in 2020 and 13% in 2030.

In 2030, total abatement potential in the sector is 60 MtCO₂e at no carbon price and 64 MtCO₂e at a carbon price of \$20/tCO₂e. The estimated net GHG mitigation potential in 2030 at various break-even prices for various countries and regions are presented in Table 4.

Figure 3. Global MAC Curve for Non-CO₂ Reductions from Non-Rice Cropland Soils (Constant Area Case)

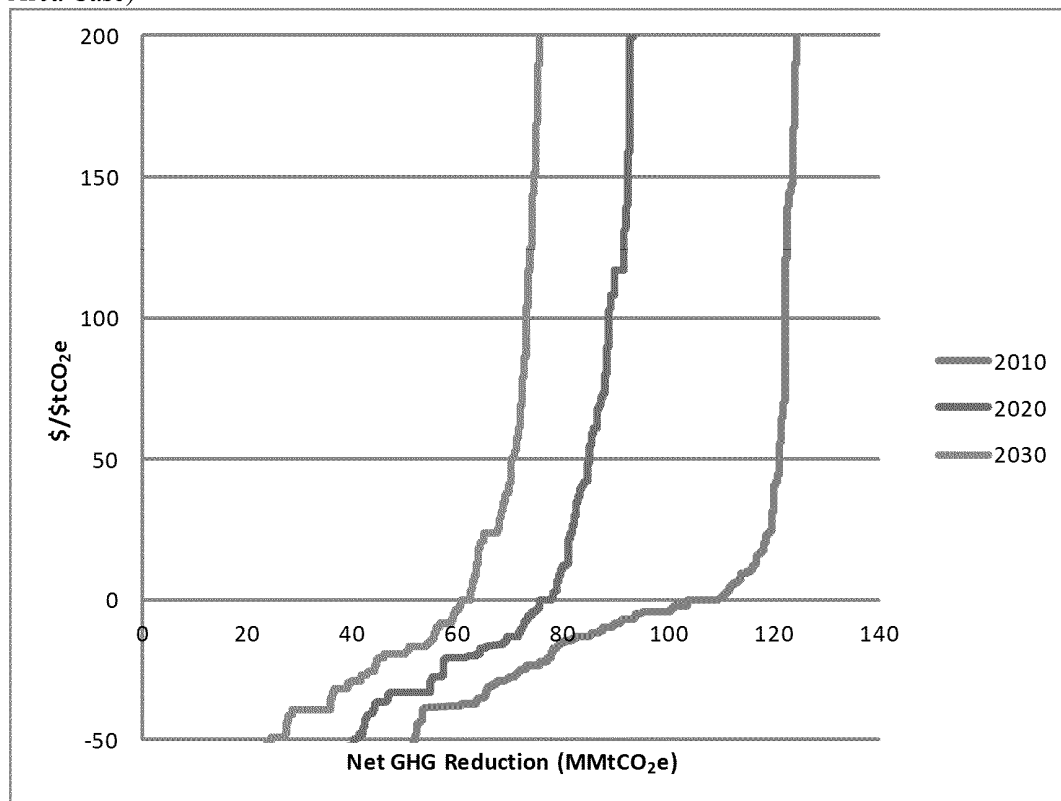


Table 4. Abatement Potential by Region at Selected Break-Even Prices in 2030 (MtCO₂e)

Country/Region	Break-Even Price (\$/tCO ₂ e)										
	-10	-5	0	5	10	15	20	30	50	100	100+
Top 5 Emitting Countries											
China	24.1	24.1	24.1	24.1	24.2	24.2	24.2	24.8	24.8	24.8	25.4
U.S.A	8.7	8.7	8.8	8.8	8.8	8.8	8.8	11.4	11.4	11.4	13.2
India	6.4	8.8	9.5	9.5	9.9	9.9	9.9	9.9	10.2	10.2	11.5
Brazil	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	2.1
Argentina	0.6	0.6	0.6	0.6	0.7	0.7	0.7	0.7	0.7	0.7	1.0
Rest of Region											
Africa	2.4	2.5	3.0	3.1	3.1	3.2	3.2	3.2	3.3	3.7	4.7
Asia	3.8	3.9	4.2	4.3	4.3	4.3	4.3	4.3	4.6	4.8	5.2
Central & South America	1.1	2.0	2.0	2.1	2.2	2.2	2.2	2.3	2.4	2.5	3.1
Eurasia	0.3	0.3	0.4	0.4	0.4	0.4	0.4	0.5	1.6	2.3	2.6
Europe	6.6	6.7	7.3	7.4	7.5	7.5	7.6	7.9	8.0	9.4	11.7
Middle East	0.6	0.7	1.3	1.3	1.3	1.3	1.7	1.7	1.8	1.8	2.1
North America	0.9	0.9	0.9	0.9	1.0	1.0	1.0	1.1	1.1	1.2	2.1
World Total	55.7	59.4	62.2	62.6	63.4	63.6	64.2	68.0	70.1	73.0	84.7

GHG mitigation (FOR SOIL EMISSIONS IN CROPLAND) and its cost-effectiveness vary significantly by country or region. At the regional level, Asia appears to have the most significant potential for reducing net GHG emissions from cropland soil management, followed by North America and Europe. Figure 4 displays the MAC curve of the top-five emitting countries in 2010 and 2030.

China has the largest mitigation potential of any country and is also among the few countries that have mitigation potential that increases over the 2010-2030 period. This appears to be related to fertilizer use that is much higher than optimal.⁶ This suggests that N₂O emissions may be reduced without a yield, or soil C, penalty.

⁶ In the DAYCENT autofert scenario, where the model determined the optimal fertilizer rates, fertilizer use typically decreased in China from 30 percent to over 50 percent for major crops as compared to baseline levels. N₂O emissions also declined. (FNT: again, with all the model uncertainties associated to the exercise; plus you were comparing a baseline where you used statistical data with one where you let the model do what it pleased. The comparison between the two cases is not really appropriate)

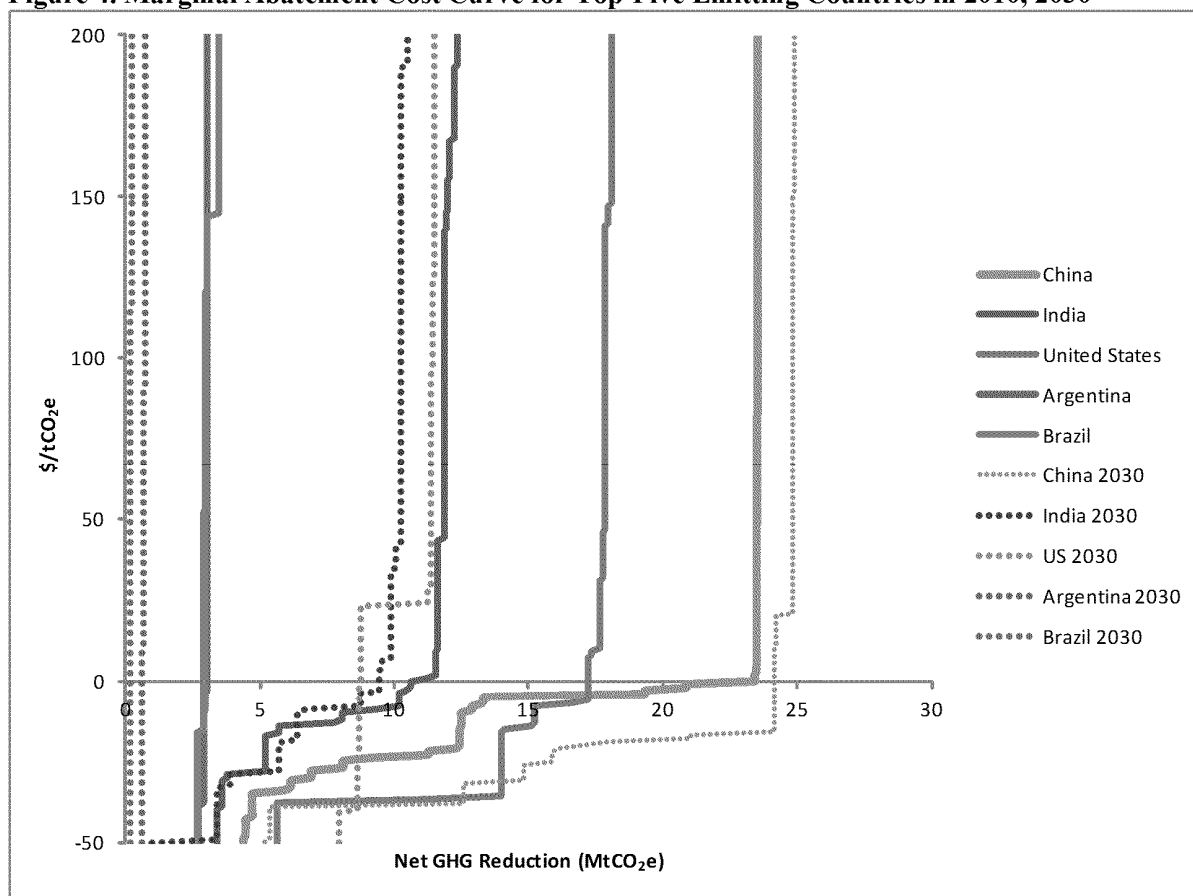
Figure 4. Marginal Abatement Cost Curve for Top-Five Emitting Countries in 2010, 2030

Table 5 below presents a summary of estimated global total mitigation potential by mitigation option. Overall the MAC analysis results suggest that auto-fertilization, a management practice that optimizes N fertilizer application to achieve maximum crop yields, is the single most significant source of GHG mitigation in cropland soil management. This option accounts for approximately 44% of the total global mitigation potential in 2010 and 2030. The second most significant mitigation option is no-till practice, accounting for about 39% of the global total

mitigation potential.⁷ Reduction in N fertilizer application and adoption of nitrification inhibitors would also make substantial contributions to net GHG reductions from cropland soil management.

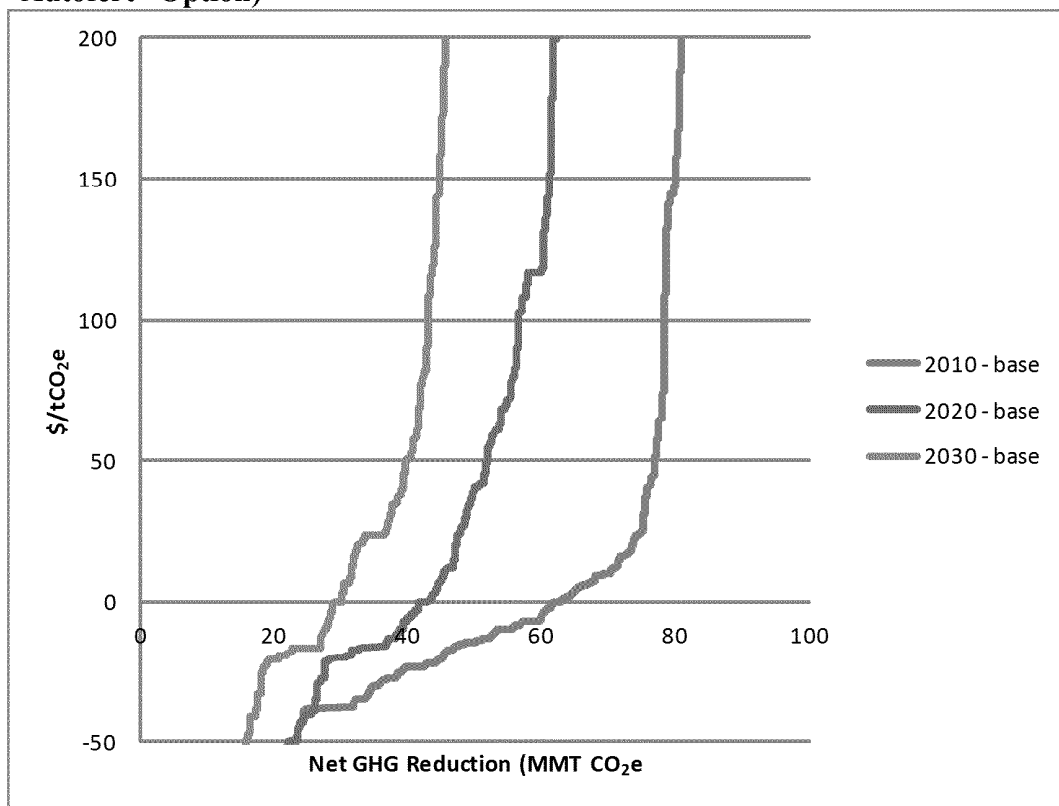
⁷ As discussed above, mitigation potential from adoption of no-till practice is likely over-estimated with 100% conventional tillage assumed in the business-as-usual baseline.

Table 5. Global Total Abatement Potential from Cropland Soils by Measure (MtCO₂e)

	GHG Mitigation by Option (total all prices)					
	2010		2020		2030	
fert080	11.15	8.62%	14.28	14.2%	17.69	20.9%
fert120	0.24	0.19%	0.03	0.0%	0.00	0.0%
r100	0.28	0.21%	0.15	0.1%	0.03	0.0%
ninhib	5.98	4.62%	5.62	5.6%	6.13	7.2%
splitfert	3.58	2.77%	2.65	2.6%	2.18	2.6%
notill	50.80	39.26%	35.37	35.3%	20.95	24.7%
autofert	57.35	44.33%	42.24	42.1%	37.69	44.5%
TOTAL	129.37	100.00%	100.34	100.0%	84.66	100.0%

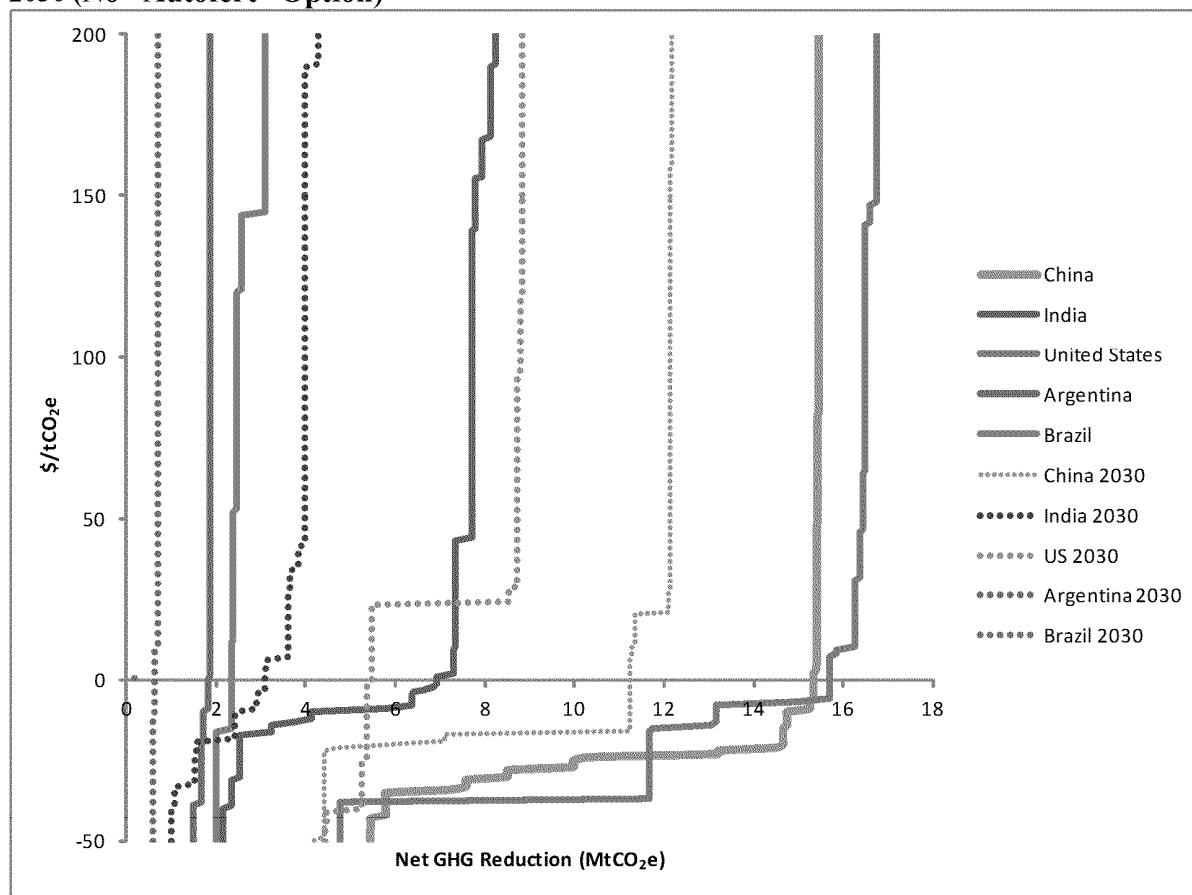
These results suggest that the MAC analysis may be particularly sensitive to assumptions in the autofert scenario. The robustness of the MAC curves was tested by eliminating the autofert option. This analysis resulted in the global MAC curve shown in Figure 5, and summarized in Table 6. With autofert removed from the analysis, global mitigation falls from a maximum of 129 Mt to 86 Mt in 2010. Global mitigation in 2030 falls from a maximum of 85 Mt to about 56Mt.

Figure 6 shows the effect on the top 5 countries. With the autofert option removed from the analysis, China's mitigation 2010 potential falls below that in the US throughout much of the price range, and 2030 mitigation potential falls even further, below the 2010 potential in China.

Figure 5: Global MAC Curve for Non-CO₂ Reductions from Non-Rice Cropland Soils (No “Autofert” Option)**Table 6: Global Total Abatement Potential from Cropland Soils by Measure (MtCO₂e) (No “Autofert” Option)**

	GHG Mitigation by Option (total all prices)					
	2010		2020		2030	
fert080	14.05	16%	18.09	26%	22.39	40.1%
fert120	0.30	0%	0.03	0%	0.00	0.0%
r100	0.33	0%	0.18	0%	0.04	0.1%
ninhib	7.08	8%	6.46	9%	6.66	11.9%
splitfert	4.38	5%	3.14	4%	2.36	4.2%
notill	60.82	70%	42.47	60%	24.40	43.7%
autofert	0.00	0%	0.00	0%	0.00	0.0%
TOTAL	86.94	100%	70.37	100%	55.85	100.0%

Figure 6: Figure 4. Marginal Abatement Cost Curve for Top-Five Emitting Countries in 2010, 2030 (No “Autofert” Option)



5. Uncertainties and Limitations

Given the complexities of the global crop production sector, the estimated GHG mitigation potential and marginal abatement cost curves are subject to a number of uncertainties and limitations:

- **Availability and quality of data to represent the highly complex and heterogeneous crop production systems of the world.** Compared to the previous EPA marginal abatement cost curve analysis (USEPA, 2006), there are major improvements in the datasets used to represent the global crop production systems and the business-as-usual baseline conditions. However, data in some areas, such as management practices which have significant influence on the GHG fluxes, are not always available for all countries or regions. Approximations had to be made based on limited literature or expert

judgement. Moreover, collecting and developing regionally specific cost estimates of emerging and/or not widely adopted management practices or mitigation measures has been a challenge and in some cases global datasets had to be used.

- ***Biophysical modeling uncertainties.*** The evaluation of simulated crop yields against observed yields suggests that DAYCENT modeling performance varies by crop⁸, leading to potential biases in estimated GHG emissions. Model structure is found to be the largest contributor to uncertainty in simulation results using DAYCENT, typically more than 75% of overall uncertainty in estimates (Ogle et al. 2010, Del Grosso et al. 2010). Further model evaluation will be carried out to understand potential model bias and prediction error using empirical based procedure discussed in Ogle et al. (2007). In addition, soil carbon, which has a significant impact on the net GHG emissions and mitigation potential from the sector, is particularly challenging to simulate given the lack of monitoring data at the global scale. Sensitivity tests would be useful to assess how alternative modeling approaches and assumptions may influence modeling results.
- ***Optimistic assumptions on technology adoption.*** The analysis assumes that if mitigation technology is considered feasible in a country or region, it is fully adopted in 2010 and through the analysis period. Research suggests that adoption of new technology in the agricultural sector is a gradual process and various factors potentially slow the adoption of a new GHG-mitigating technology (e.g., farm characteristics, access to information and capital, and cultural and institutional conditions). The mitigation potential presented in this analysis should be viewed to represent the technical potential of the mitigation options analyzed.
- ***Potential interactions of multiple mitigation measures are not fully addressed in this analysis.*** In this analysis, mitigation options are applied to independent segments of the crop production systems to avoid double counting. In reality, multiple mitigation options can be applied, and their order of adoption and potential interactions may affect the aggregate GHG mitigation. Alternative approach should be investigated to provide more realistic representation of economic applicability of potential mitigation measures.

⁸ Overall, simulated yields for maize agree reasonably well with observed yields; simulated average yields for wheat, barley and sorghum are lower than observed yields (FNT this in a model is usually a very bad sign. Modeled yields should always be higher, rather than lower, than actual yeils, since they do not represent negative impacts such as pests, extreme events, flooding, etc etc etc) ; simulated average yields for soybean are above observed yields.

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Appendix A. Description of the input data used in DAYCENT simulations

Data Type	Description	Source
Daily Weather	Daily weather for 1901 – 2010 at 0.5 degree resolution in latitude by longitude. This includes daily minimum temperature, daily maximum temperature, and daily precipitation.	The original data source was the MsTMIP project's 6 hour CRU + NCEP combined data. This was aggregated to daily, and all non-land cells were removed. http://nacp.ornl.gov/MsTMIP.shtml
Soils	This data is the same as was used for previous the DAYCENT global simulations. The data is at 0.5 degree resolution in latitude by longitude and includes sand, silt, clay, bulk density, pH, number of soil layers.	FAO, 1996. The Digitized Soil Map of the World Including Derived Soil Properties, CDROM. Food and Agriculture Organization, Rome.
Agricultural cells to simulate	This mask was computed from the fraction of agricultural area. The fraction of agricultural area is provided at 5 minute resolution in latitude by longitude. This data was aggregated it to 0.5 degree resolution by latitude and longitude. We selected cells where fraction of cropland area $\geq 5\%$.	Agricultural Lands in the Year 2000. Described in the publication, Ramankutty et al. (2008), "Farming the planet: 1. Geographic distribution of global agricultural lands in the year 2000", Global Biogeochemical Cycles, Vol. 22, GB1003, doi:10.1029/2007GB002952.
Crop masks for maize, winter wheat, spring wheat, winter barley, spring barley, sorghum, and soybean	Crop-specific masks indicating where to simulate each crop. Each crop mask is a subset of the agricultural cells to simulate, described above. This data was provided at 0.5 degree resolution in latitude by longitude. Note: Although separate crop masks were provided for winter and spring wheat, there was almost no difference between these masks. Likewise for winter and spring barley. The main difference between winter and spring varieties was the planting and harvest dates (see below).	FAO data. These files were produced by Mirella Salvatore at the FAO, and Aaron Berdanier.
Irrigated Areas by crop type	Crop-specific data with the fraction of cropland area that is irrigated. This data was provided at 0.5 degree resolution in latitude by	FAO data. These files were produced by Mirella Salvatore at the FAO, and Aaron Berdanier.

	longitude for all years between 1985 and 2008. Irrigation was simulated for modern agriculture (year 1951 or later) for cells where the irrigated fraction > 0.0 for any year between 1985 and 2008. The fraction of cropland irrigated in 2008 was used in the post-processing step to aggregate model results.	
Initial Year of Cultivation	Fraction of area in agriculture for years 1700-2007 at 0.5 degree resolution in latitude by longitude. We computed the first year when the fraction of agricultural area was 50% of the fraction of cropland area in 2000 – this determined the year of plow-out for the cell.	Global Cropland and Pasture Data from 1700-2007. This is a beta release of an updated version of our original historical cropland data set that spanned the 1700-1992 period. The original data set was described in the publication by Ramankutty and Foley (1999) in Global Biogeochemical Cycles. This release updates the data to the 1700-2007 time period. (http://www.geog.mcgill.ca/landuse/pub/Data/Histlanduse/ , Accessed June 29, 2012).
Crop Specific Planting and Harvest Dates	Planting date (<u>day of year</u>) and harvest date (<u>day of year</u>) for each crop at 0.5 degree resolution in latitude by longitude: Barley (winter), Barley (spring), Maize (main season), Maize(second season), Sorghum (main season) , Sorghum second season), Soybeans, Wheat (winter), Wheat (spring)	Sacks, W.J., D. Deryng, J.A. Foley, and N. Ramankutty (2010). Crop planting dates: an analysis of global patterns. Global Ecology and Biogeography 19, 607-620. DOI: 10.1111/j.1466-8238.2010.00551.x.
Harvest type and residue removal rate by crop.	Harvest type and residue removal rate by crop at 0.5 degree resolution in latitude by longitude by crop. The harvest type designates a grain or non-grain harvest (for this exercise, all crops had grain harvests). The residue removal rate determines the percentage of residue removed from the field at time of harvest. Residue includes all above-ground plant material after grain is	FAO data. These files were produced by Mirella Salvatore at the FAO, and Aaron Berdanier.

	removed.	
Tillage, planting, and weeding practices by country and by crop	Tillage, planting, and weeding practices by crop for developed countries (conventional), develop countries (conservation), and less developed countries. Crops are categorized as small grain (barley, wheat) or large grain (maize, sorghum, soybean). These practices determine the intensity of soil disturbance simulated for each event.	FAO data. These files were produced by Mirella Salvatore at the FAO, and Aaron Berdanier.
N application rates : includes fertilizer N and manure N	<p>Annual N application rates including N fertilizer plus manure N ($\text{gN m}^{-2} \text{yr}^{-1}$) at 0.5 degree resolution in latitude by longitude by crop for years 1985 - 2008. N application rates from 1950 – 1984 were linearly interpolated between 0.0 in 1950 and the 1985 rate. N application rates for 2009 – 2035 were set to the 2008 rate.</p> <p>Note: There was no data about the relative amount of fertilizer N and manure N.</p>	FAO data. These files were produced by Mirella Salvatore at the FAO, and Aaron Berdanier.
Harvested Areas and Yields by crop type in year 2000.	<p>Harvested Area (proportion of grid cell area) and Yield (tons/ha). The data is provided at 5 minute resolution in latitude by longitude. We aggregated the data to a 0.5 degree resolution.</p> <ol style="list-style-type: none"> 1) The measured yields were compared to simulated yields from the baseline simulation. 2) The harvested area fraction was used in the post-processing step for aggregating model results. 	Harvested Area and Yields of 175 crops (M3-Crops Data). Monfreda et al. (2008), "Farming the planet: 2. Geographic distribution of crop areas, yields, physiological types, and net primary production in the year 2000", Global Biogeochemical Cycles, Vol.22, GB1022, doi:10.1029/2007GB002947.

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[LEAD Task 5 report- DRAFT July 24 2013 clean.docx](#)
[LEAD Emission Factors Methodology 07.01.2013.pptx](#)

Hi-

Attached is the Emission Factor report we developed for USAID/RDMA, *Current Challenges and Priorities for Greenhouse Gas Emission Factor Improvement in Select Asian Countries*. This version is still in draft form, and we expect to finalize and post to the LEAD website once we receive feedback from the country missions in a few weeks. I also developed the attached presentation, which provides a nice summary of the study results.

Please let us know if you have any feedback on the report and/or presentation.

Thanks,

Lauren

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Low Emissions Asian Development (LEAD) Program Current Challenges and Priorities for Greenhouse Gas Emission Factor Improvement in Select Asian Countries

July 2013

This document was prepared for the United States Agency for International Development (USAID) Regional Development Mission for Asia (RDMA) by ICF International under Contract No. AID-486-C-11-00002.

The contents are not the responsibility of USAID and do not necessarily reflect the views of the United States Government.

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Current Challenges and Priorities for Greenhouse Gas Emission Factor Improvement in Select Asian Countries

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ACRONYMS AND ABBREVIATIONS

ACCMIP	Atmospheric Chemistry and Climate Model Intercomparison Project
AD	activity data
AFOLU	agriculture, forestry, and other land use
BAPPENAS	Ministry of National Development Planning (Indonesia)
BAU	business as usual
BUR	Biennial Update Report
CAI Asia	Clean Air Asia
CCEB	Catalyzing Clean Energy in Bangladesh (USAID)
CCSAP	Climate Change Strategy and Action Plan (Bangladesh)
C/D	chassis dynamometer
CFC	chlorofluorocarbon
CH ₄	methane
CII	Confederation of Indian Industries
CO	carbon monoxide
CO ₂	carbon dioxide
COP	Conference of Parties
CORINAIR	Core Inventory of Air Emissions in Europe
CSEF	country-specific emission factor
DENR	Department of Environment and Natural Resources (Philippines)
DFID	Department for International Development (UK)
DoE	Department of Environment (Bangladesh, Malaysia)
DOE	Department of Energy (Philippines)
EC-LEDs	Enhancing Capacity for Low Emission Development Strategies
EFDB	emission factor database
EGAT	Economic Growth, Agriculture, and Trade Bureau (USAID)
EPA SEA (II)	Environmental Protection Agency Regional Capacity Building for Sustainable National Greenhouse Gas Inventory Management Systems in Southeast Asia Phase II
ESMAP	Energy Sector Management Assistance Program (UNDP)
FAO	Food and Agricultural Organization
GAINS	Greenhouse Gas and Air pollution Interactions and Synergies model
Gg CO ₂ -eq.	Gigagram of carbon dioxide equivalent
GGR	Green Growth Roadmap (Cambodia)
GHG	greenhouse gas
GIZ	Gesellschaft für Internationale Zusammenarbeit (or German Agency for International Cooperation)
GOI	Government of Indonesia
HCFC	hydrochlorofluorocarbon
HFC	hydrofluorocarbon
ICCC	Indonesia Climate Change Center
ICLEI	Local Governments for Sustainability (formerly International Council for Local Environmental Initiatives)
IEA	International Energy Agency
IGES	Institute for Global Environmental Strategies (Japan)
IIASA	International Institute for Applied Systems Analysis
INCAS	Indonesian National Carbon Accounting System

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INCCA	Indian Network for Climate Change Assessment
IPAC	Integrated Protected Area Co-management (USAID)
IPCC	Intergovernmental Panel on Climate Change
IPPU	Industrial Processes and Product Use
IRRI	International Rice Research Institute
JICA	Japan International Cooperation Agency
KCA	key category analysis
LEAD	Low Emissions Asian Development program (USAID)
LEAF	Lowering Emissions in Asia's Forests program (USAID)
LEDs	low emission development strategies
LULUCF	land use, land-use change, and forestry
MARD	Ministry of Agriculture and Rural Development (Vietnam)
MGCT	Malaysia Global Training Center
MLITT	Ministry of Land, Infrastructure, Transport, and Tourism (Philippines)
MOIT	Ministry of Industry and Trade (Vietnam)
MONRE	Ministry of Natural Resources and Environment (Vietnam)
MPI	Ministry of Planning and Investment (Vietnam)
MRV	monitoring, reporting, and verification
N ₂ O	nitrous oxide
NAMA	Nationally Appropriate Mitigation Actions
NASA	National Aeronautics and Space Administration
NC	National Communication
NC1	Initial National Communication
NC2	Second National Communication
NC3	Third National Communication
NCAR	National Center for Atmospheric Research (USG)
NMVOC	non-methane volatile organic compound
NO _x	nitrous oxides
NOAA	National Oceanic and Atmospheric Administration (USG)
NRE	Ministry of Natural Resource and Environment (Malaysia)
NSCC	National Strategy on Climate Change (Indonesia)
NSF	National Science Foundation (USG)
QA/QC	quality assurance/quality control
PCCC	Philippines Climate Change Commission
PFC	perfluorocarbon
RAD-GRK	Local Action Plan for GHG Emission Reduction (Indonesia)
RAINS	Regional Air pollution Information and Simulation
RAN-GRK	National Action Plan for Greenhouse Gas Emission Reductions (Indonesia)
REAS	Regional Emission inventory in Asia
SF ₆	sulphur hexafluoride
SIGN	National GHG Inventory System (Indonesia)
SLCP	Short-lived climate pollutant
SOP	standard operating procedures
TEAP	Technology and Economic Assessment Panel
TRACE-P	Transport and Chemical Evolution over the Pacific
T-VER	Thailand Verified Emissions Reduction program
UNDP	United Nations Development Program
UNEP	United Nations Environment Program

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UNFCCC	United Nations Framework Convention on Climate Change
USAID	United States Agency for International Development
USAID/RDMA	USAID Regional Development Mission for Asia
USDA/FS	United States Department of Agriculture's Forest Service
USDOE	United States Department of Energy
USEPA	United States Environmental Protection Agency
USG	United States Government
VOC	volatile organic compound
WGIA	Workshop on Greenhouse Gas Inventories in Asia (Japan)

EXECUTIVE SUMMARY

Global greenhouse gas (GHG) emissions have doubled since the early 1970s, driven mainly by economic growth and increasing fossil-energy use.¹ Enabling and encouraging low-carbon, climate-resilient economic development is imperative and a major emphasis of the Low Emissions Asian Development (LEAD) program funded by the United States Agency for International Development Regional Development Mission for Asia (USAID/RDMA). LEAD builds the capacity of government and non-governmental partners in Asia to develop and use low emission development strategies (LEDS) in four interrelated areas: analysis and modeling of economic development pathways, emissions trajectories, and technology options; GHG inventories and accounting; carbon market development; and regional cooperation. The LEAD program involves up to 11 countries: Bangladesh, Cambodia, India, Indonesia, Laos, Malaysia, Nepal, Papua New Guinea, Philippines, Thailand, and Vietnam.

This report, *Current Challenges and Priorities for Greenhouse Gas Emission Factor Improvement in Select Asian Countries*, focuses on a key initiative of the LEAD program, namely to improve GHG inventories and GHG accounting systems and practices. The national GHG inventories in Asia exhibit diversity in their methodological complexity, accuracy, and specificity to national circumstances. In addition, the majority of GHG inventory estimates rely on default emission factors provided by the Intergovernmental Panel on Climate Change (IPCC), as opposed to using country-specific emission factors (CSEFs) tailored to country conditions. The use of simplified representations of emission factors with default values that do not reflect in-country conditions is one of the main sources of uncertainty within national GHG inventories. Use of CSEFs instead of default values can reduce the level of uncertainty in national GHG inventories.

This Emission Factor Improvement Report summarizes an analysis of emission factors used in LEAD program country GHG inventories and recommends six such emission factors for further research and development. The report also identifies other emission factors for which research and development could be supported by other development partners, in order to support the improvement of national GHG inventories and fulfill one of the LEAD program goals. Short-lived climate pollutants (SLCPs) include black carbon, methane and tropospheric ozone. As their name implies, SLCPs have a relatively short lifetime in the atmosphere and thus a strong global warming effect. Reducing SLCP emissions provides an opportunity to reduce the rate of climate change over the next few decades by reducing associated near-term future warming.² Mitigating these pollutants can play a pivotal role in reducing current and near-future warming, while additional mitigation efforts are underway to curb longer living GHGs.³ Reducing SLCP emissions provides an opportunity to reduce the rate of climate change over the next few decades by reducing associated near-term future warming.⁴ Mitigating these pollutants can play a pivotal role in reducing current and near-future warming, while additional mitigation efforts are underway to curb longer living GHGs.⁵ Currently, Asia as a whole accounts for 40 percent of worldwide black carbon emissions, with Southeast Asia representing approximately 45 percent of Asian emissions.⁶

¹ OECD (2011).

² IGSD (2012).

³ IPCC (2007b).

⁴ IGSD (2012).

⁵ IPCC (2007b).

⁶ Larmarque *et al.* (2010). For purposes of this report, Asia is defined as China, China Hong Kong SAR, China Macao SAR, Mongolia, Taiwan, Afghanistan, Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan, Sri Lanka, Brunei

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SLCPs in general are dangerous air pollutants and have adverse effects on human health, agricultural productivity, and ecosystems.⁷ Hence, an analysis of SLCPs including black carbon with a focus on emissions sources and relevant emission factors is also presented in this report.

To conduct this analysis, the research team consulted with regional stakeholders and country experts to gather input on emission factors currently used in 10 LEAD countries, and which emission factors are priorities for improvement. The research team also developed a selection framework as part of a desk study that identified key factors for prioritizing emission factors and incorporated information from LEAD country National Communications. The combination of the consultations and the desk study were synthesized to develop the recommendations.

The six emission factors recommended for improvement include:

- 1) Methane (CH₄) emissions from rice cultivation;
- 2) Carbon dioxide (CO₂) emissions from land use, land-use change, and forestry (LULUCF), in particular, changes in woody and forest biomass, conversion of forestland to grassland, soil carbon. Specific LULUCF category(s) identified by each country depend on the country and associated land use types;
- 3) CH₄ emissions from enteric fermentation;
- 4) CO₂ emissions from mobile combustion;
- 5) CO₂ emissions from coal and natural gas stationary combustion; and
- 6) Nitrous oxide (N₂O) emissions from agricultural soil management.

In addition to these GHG emission factors, the two areas of SLCP research that could benefit LEAD program countries include:

- 1) Black carbon emissions and emission factors in brick kilns and cook stoves; and
- 2) Hydrofluorocarbon (HFC) emissions and emission factors for HFC emissions from chillers, stationary air conditioning, and mobile air conditioning.

The relevance and priorities for improving these factors varies by LEAD program country. The approach for developing emission factors will also vary based on availability of country-specific data and resources. The next steps in improving emission factors include training and technical assistance that defines which emission factors need to be targeted for each country; identify existing templates/training/standards for emission factor development; examine data availability in each country; identify experts in country that can participate in training, and determine the most effective mode of training and technical assistance (e.g., regional training, targeted series of sub-regional trainings). The specific details of the approach for training will be further defined in future LEAD program work in the region and will ultimately help countries develop more accurate national GHG inventory emission estimates from which to establish potential mitigation actions.

Darussalam, Cambodia, Democratic People's Republic of Korea, East Timor, Indonesia, Lao People's Democratic Republic, Malaysia, Myanmar, Papua New Guinea, Philippines, Republic of Korea, Singapore, Thailand, and Vietnam.

⁷ UNEP (2013).

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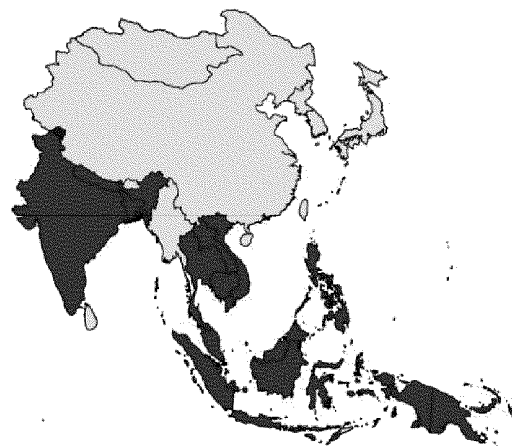
1. INTRODUCTION

Changing climatic conditions are increasing economic and social stresses throughout the world. Historically, Organization for Economic Co-operation and Development (OECD) economies have been responsible for most of the global anthropogenic greenhouse gas (GHG) emissions. However, in the coming decades increasing emissions will also be caused by high economic growth in some of the major emerging economies.⁸ By 2030, carbon dioxide (CO₂) emissions from energy use in Asia's developing countries are estimated to increase from 33 percent to 45 percent of the world total.⁹ Projections of emissions from the forest and land use sectors are highly uncertain, but they will undoubtedly be highly significant as deforestation and forest degradation continue. Climate change impacts are already being observed and developing countries face acute vulnerabilities in terms of impacts on agriculture and coastal cities. In this context, enabling and encouraging low-carbon, climate-resilient economic development is imperative.

1.1 About the Low Emissions Asian Development (LEAD) Program

The Low Emissions Asian Development (LEAD) program is designed to help Asian governments, businesses, and other institutions develop and implement frameworks for sustained low-emission development. Funded by the United States Agency for International Development Regional Development Mission for Asia (USAID/RDMA), the five-year regional program supports and enhances country-led development programs, plans, and policies to support low emission development strategies (LEDS). To build the capacity of government and non-governmental partners in developing and using LEDS, the program focuses on four interrelated areas: analysis and modeling of economic development pathways, emissions trajectories, and technology options; GHG inventories and accounting; carbon market development; and regional cooperation. This report relates to LEAD's work on GHG inventories and accounting and carbon market development.

Figure 1: LEAD program focus countries



The LEAD program works in up to 11 countries: Bangladesh, Cambodia, India, Indonesia, Laos, Malaysia, Nepal, Papua New Guinea, the Philippines, Thailand, and Vietnam. These 11 countries display great diversity in their levels of GHG emissions and in their capacities to develop LEDS and robust national GHG inventories. They display similar diversity in their abilities to engage in carbon markets as well. For many LEAD program countries, adaptation to climate change impacts is of immediate, paramount concern. Both adaptation and economic growth, and associated poverty alleviation, are higher priorities than GHG mitigation. The LEDS process is designed to strengthen these priorities while working to achieve meaningful emission reductions over time.

⁸ OECD (2011).

⁹ USAID (2011).

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LEAD complements the United States Government's (USG) global Enhancing Capacity for Low Emission Development Strategies (EC-LEDS) initiative and draws on specialized expertise from the United States Department of Energy (USDOE), United States Environmental Protection Agency (USEPA), and United States Department of Agriculture's Forest Service (USDA/FS). LEAD activities are conducted at a regional or multi-country level to draw upon the synergies and opportunities for shared learning and transfer of best practices and lessons learned. LEAD also serves as the Secretariat of the Asia LEDS Partnership, in part to help USAID/RDMA fulfill its role as Co-Chair and to support to USG commitment to the LEDS Global Partnership. In this role, the LEAD team collaborates closely with partnership members from country governments and international organizations to facilitate activities in a range of topical areas, based on demand and resources, to further peer-to-peer exchange and capacity building in LEDS planning and implementation across Asia.

One of the priorities of the LEAD program is to support national GHG inventory capacity-building and development by strengthening technical and institutional capacity to develop national GHG inventories. National GHG inventories in Asia exhibit diversity in their methodological complexity, accuracy, and specificity to national circumstances. In addition, the majority of GHG inventory estimates rely on default emission factors provided by the Intergovernmental Panel on Climate Change (IPCC), as opposed to country-specific emission factors (CSEFs) tailored to country conditions. The use of simplified representations of emission factors with default values that do not reflect in-country conditions is a primary source of uncertainty within national GHG inventories. Use of CSEFs instead of default values can reduce the level of uncertainty in national GHG inventories.

This report, *Current Challenges and Priorities for Greenhouse Gas Emission Factor Improvement in Select Asian Countries*, summarizes an analysis of emission factors used in LEAD program country GHG inventories and recommends six emission factors for further research and development. The report also identifies other emission factors for which research and development could be supported by other development partners in order to support the improvement of national GHG inventories and fulfill one of the LEAD program goals. Finally, the report also presents an analysis of black carbon and other short-lived climate pollutants (SLCPs) with a focus on emissions sources and relevant emissions factors.

To conduct the emission factor improvement analysis, a selection framework was developed and in-country consultations were conducted with the main authors leading the country national communications in 10 LEAD program countries as well as consultations with experts from regional and international organizations. The input from these activities provides the basis of the recommendations included in this report. Based on these results and recommendations, the report concludes with a series of recommended steps to develop an approach to providing training and technical assistance to governments, institutions, and the private sector on the development of more reliable GHG emission factors. The training and technical assistance programs could be carried out by LEAD as well as other international and national development partners in the region.

1.2 LEAD and GHG Inventories

A key component of the LEAD program is provision of regional technical assistance and training to support institutional capacity building, improved understanding of GHG estimation methodologies, data collection and management systems, inventory preparation and reporting processes, and related activities. Training and technical assistance programs are targeted towards a range of key national and subnational government agencies, universities and research institutions, non-governmental

organizations, the private sector, and others. Over the course of the program, LEAD will provide technical assistance and training that will support introduction and demonstration of emission factors and emissions calculation software and methodologies, collection systems for activity data and data management systems, as well as demonstration, sharing, and replication of successful models. The LEAD team will also work toward increasing the overall information available on various governments' progress in promoting emissions reductions. These activities will build on other tasks under the LEAD program, including emission factor improvement and LEDS development and implementation.

The LEAD program is coordinating closely with various USG agencies (e.g., USEPA, USDA/FS, and USDOE), USAID's Bureau for Economic Growth, Education and Environment (E3), and bilateral USAID missions that are supporting GHG inventory activities and related components of LEDS activities in the region. This report presents the process for identifying emission factors for recommended improvements and provides recommended next steps for determining an approach for developing and providing training and technical assistance. The remainder of this report is organized as follows:

Section 2 *GHG Emission Factor Overview* provides a background on Non-Annex I countries National Communications submissions to the United Nations Framework Convention on Climate Change (UNFCCC), principles of GHG emissions calculations, and efforts from key relevant global and regional organizations on emission factor improvement;

Section 3 *In-Country Consultations* summarizes the feedback received for each country during in-country consultations;

Section 4 *Selection Framework* describes the purpose and application of the selection framework with respect to assessing emissions factor elements in each of the 10 LEAD countries studied for this report.

Section 5 *Short Lived Climate Pollutants (SLCPs)* describes the process for evaluating black carbon and other SLCPs, provides a brief analysis of emissions sources and emissions factors, and offers recommendations for future improvement.

Section 6 *Recommendations and Prioritization for Emission Factor Improvement* identifies and recommends emissions factors for improvement.

Section 7 *Next Steps for Determining an Approach for Training and Technical Assistance* provides recommendations on appropriate next steps to take to develop and provide training and technical assistance.

2. GHG EMISSION FACTOR OVERVIEW

2.1 Background

The countries included in the LEAD program are non-Annex I countries. These are developing countries recognized by the UNFCCC as economically and environmentally vulnerable to the adverse impacts of climate change. While non-Annex I countries do not have timeframes for submitting NCs, the UNFCCC recommends that these documents should be submitted within the initial four years¹⁰ of the initial

¹⁰ UNFCCC (2012)

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disbursement of financial resources from the Global Environment Facility (GEF).¹¹ Under UNFCCC guidelines, all Parties to the convention must develop and publish a national inventory of the GHGs that are not controlled by the Montreal Protocol. These gases include carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O), perfluorocarbons (PFCs), hydrofluorocarbons (HFCs), and sulphur hexafluoride (SF₆). The national GHG inventory is an essential first step in reporting as it identifies the GHG emissions of the country, evaluates the magnitude of the emissions, and sets a baseline from which to measure future mitigation actions.

As of April 3, 2013, all LEAD program countries had submitted their Initial National Communication (NC1), and most were nearing completion of their Second National Communication (NC2). Six LEAD countries—Bangladesh, India, Indonesia, Malaysia, Thailand, and Vietnam—had submitted their NC2s and had initiated work on their Third National Communication (NC3).

The Durban Decision at the 17th Conference of the Parties (COP17) of the UNFCCC stated that, “Consistent with their capabilities and the level of support provided for reporting, countries should also submit biennial update reports (BUR) containing updates of national greenhouse gas inventories, including a national inventory report and information on mitigation actions, needs, and support received.” The eleven Non-Annex I countries included in the LEAD program are working towards developing their BURs and are seeking to improve their GHG inventories. BURs are due every two years, with first reports due in 2014. These BURs will complement LEAD program country efforts to develop their national communications.

GHG Emissions Calculation

The calculation of GHG emissions from a source generally involves two main components: activity data and GHG-specific emissions factors. A key exception to this description is if direct measurements, such as continuous emissions monitoring systems (CEMS), are used to quantify emissions directly without the use of either activity data or emissions factors (such as from a smokestack, in the power generation sector). In addition, activity data and emissions can be more easily applied to deforestation but not to degradation which requires much more complexity. The quality of GHG inventories depends on reliable and accurate inputs of these two components. As part of improving the quality of GHG estimates in their national communications, countries are interested in continually refining the methodologies applied for activity data collection and estimates and in developing improved CSEFs.

In its simplest form, the GHG emission calculation for each GHG is represented by the following equation:

$$\text{GHG Emissions} = \text{Activity Data (AD)} \times \text{Emission Factor (EF)}$$

Activity data are defined as the magnitude of activity resulting in emissions or removals occurring during a given period of time. An emission factor is the emission rate of a given greenhouse gas for a given source, relative to the unit(s) of activity. In the agricultural context, for example, activity data can range from the amount of fuel consumption to the amount of crop production, depending on the source of the emissions or removals. Like activity data the emission factor can be based on direct measurement data and can range from carbon dioxide emitted per gallon of fuel consumed to methane emissions per hectare of rice production. In addition, rather than emitting GHGs, some land use-related activities

¹¹ UNFCCC (2013)

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remove (or sequester) GHGs. In these instances, a negative value for the emission factor is used that represents CO₂ removals from the atmosphere.

Given resource and other constraints, emission factors should reflect national/regional circumstances to the greatest extent possible, because emission factor values vary by emission source, as well as by country-specific conditions, practices, and activities. Country-specific emission factors are not available for many emission sources in LEAD country inventories, and as a result, default emission factors from the IPCC guidelines are used. These default factors are often from international statistics and may represent a global or region-specific value, and may therefore not reflect the actual conditions of country-specific activities.

The use of CSEFs not only improves the accuracy of emissions estimates, but also allows countries to apply higher tier IPCC methods. IPCC Guidelines categorize methodologies used for GHG emissions estimation in terms of tiers, and recommend more detailed, higher tier methods be implemented for key categories.¹² The IPCC tiers range from basic methodologies for Tier 1 estimates, using default emission factors (that may be based on national, regional, or international data) and more generic activity data (that may be based on national or regional statistics), to Tier 2 estimates utilizing CSEFs and more detailed activity data, and finally to Tier 3 methods using detailed emission models or actual direct measurements of emissions. IPCC guidelines state that “the inventory compiler should use different tiers for different source categories, depending on the importance of the source category within the national total and the availability of resources in terms of time, work force, sophisticated models, and budget.” In other words, the effort of developing more detailed, higher tier methods should be focused on key categories, and those emission sources that represent the greatest share of national emissions.

To illustrate the importance of CSEFs, the calculation below provides the differences in emission estimates in the application of default IPCC emission factors versus CSEFs to estimate methane emissions from rice production in the Philippines. Rice is one of the most important agricultural products in the region, and emissions of methane from rice production are dependent on soil properties, temperature, cultural cultivation practices (e.g., rainfall, irrigation), and rice varieties. A study conducted by the International Rice Research Institute (IRRI) measured methane emissions from rice production in the Philippines, and CSEFs for methane emissions for rice production were developed for the country using the data collected through this effort.¹³

For irrigated rice cultivation systems in the Philippines, the emission factor of 2.3 kilograms methane per cultivated hectare per day (kg CH₄/ha/day) was derived based on collected data, whereas the default emission factor for irrigated rice cultivation provided in the 2006 IPCC Guidelines is 5.9 kg CH₄/ha/day. The CSEF therefore represents a 61 percent decrease over the default emission factor provided by the IPCC Guidelines. Similarly, using IRRI data on rain-fed ecosystems in the Philippines, an emission factor of 0.4 kg CH₄/ha/day was derived, whereas the default emission factor provided in the 2006 IPCC Guidelines for rainfed systems is 3.54 kg CH₄/ha/day. The CSEF represents an 89 percent decrease over the default emission factor provided in the IPCC Guidelines. Developing and using country-specific values more accurately characterizes methane emissions from rice production and provides a more accurate baseline estimate against which to measure future emissions reductions.

¹² A key category is one that is prioritized within the national inventory system because its estimate has a significant influence on a country's total inventory of GHGs in terms of the absolute level, the trend, or the uncertainty in the emissions and removals. Whenever the term key category is used, it includes both source and sink categories.

¹³ Wassman, *et. al.* (2000).

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Rice Methane Emissions Using IPCC Default vs. Country-Specific Emission Factors for the Philippines

Irrigated rice fields = 2,017,000 hectares (ha)

Rainfed rice fields = 1,433,000 hectares (ha)

Irrigated CH₄ emissions (IPCC Default) = (2,017,000 ha x 114 days x 5.9 kg/ha/day)/1,000 = **1,356,634 kg**Irrigated CH₄ emissions (CSEF) = (2,017,000 ha x 114 days x 2.3 kg/ha/day)/1,000 = **528,857 kg****Difference = - 827,777 kg methane**Rainfed CH₄ emissions (IPCC Default) = (1,433,000 ha x 113 days x 3.54 kg/ha/day)/1,000 = **573,229 kg**Rainfed CH₄ emissions (CSEF) = (1,433,000 ha x 113 days x 0.4 kg/ha/day)/1,000 = **64,772 kg****Difference = - 508.457 kg methane**

2.2 Current Activities on Emission Factor Improvement

A number of ongoing activities and research efforts are underway to improve emission factors for use in GHG inventories. Among these efforts are the development of emission factor databases, workshops on emission factor improvements in the Asia region, and programs geared towards developing tools and standard operating procedures that enable a country to develop country-specific emission factors. This section highlights these activities. While not exhaustive, the list below illustrates some of the major activities underway both globally and regionally that are of significant relevance to the 10 LEAD countries covered in this report.

IPCC Emission Factor Database

The IPCC set out to establish a global emission factor database (EFDB) in 2000. The EFDB provides current default emission factors to countries complying with the UNFCCC requirement for GHG reporting. The EFDB complements the IPCC methodology reports, including the 1996 and 2006 *IPCC Guidelines for National Greenhouse Gas Inventories* and the 2001 IPCC report on *Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories*.¹⁴ The EFDB also provides a communication platform for globally distributing and commenting on new measurement data and research.¹⁵

The first version of the EFDB was published in 2003. Since then the database has become a widely recognized and utilized resource. In the current version (2.3), emission factors are divided into seven sectors based on categories defined in the 1996 IPCC Guidelines: Energy; Industrial Processes; Solvent and Other Product Use; Agriculture; Land-Use Change and Forestry; Waste; and Other. For the 2006 IPCC Guidelines, emission factors are divided into five sectors: Energy; Industrial Processes and Product Use; Waste; Other; and Agriculture, Forestry, and Other Land Use (AFOLU).¹⁶ A large number of emission factors provided in the database are default values and categorized as global averages or categorized by climate (e.g., tropical, boreal, temperate), rather than country. Since not all developing countries have the expertise and/or resources required to develop CSEFs, the database provides countries with a standardized methodology to estimate emissions by applying default emission factors as well as providing a foundation of measurement data and research to develop their own future emission factors.

¹⁴ See <http://www.epa.gov/ttnchie1/conference/ei13/datamgt/mangino.pdf>

¹⁵ See <http://ebookbrowse.com/ipcc-efdb-pdf-d399449921>

¹⁶ See <http://www.ipcc-nggip.iges.or.jp/EFDB/main.php>

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EFDB users contribute to the database by proposing emission factors to the EFDB Editorial Board. The EFDB Editorial Board is responsible for evaluating the proposals using well-defined criteria, which include robustness, applicability, and documentation.¹⁷ Governments and international organizations last nominated experts to become new members of the Editorial Board in 2010.

The EFDB criteria are a vital component of the IPCC's strategy to improve emission factor quality and availability. To determine whether an emission factor is robust, the Editorial Board examines verified raw data and models based on verified data, plus thoroughly justified assumptions coupled with an uncertainty assessment. The Editorial Board also considers whether the emission factors address all applicability properties. These properties include:

- Technologies/Practices
- Parameters/Conditions
- Region/Regional Conditions
- Abatement/Control Technologies

Lastly, the Editorial Board requires that each emission factor is thoroughly documented and that all technical references are internationally published journals, books, or reports.¹⁸ Since 2010, the Editorial Board has accepted three proposals, adding 25 individual emission factors and two emission factor datasets from the Core Inventory of Air Emissions in Europe (CORINAIR) and the USEPA.¹⁹

The Food and Agricultural Organization (FAO) Database

The Food and Agricultural Organization (FAO) has played a proactive role in recent years to conduct research, facilitate capacity building, and undertake projects focused on the intersection of agriculture and climate change, including GHG emissions quantification, abatement, and adaptation. FAO has developed a global database, FAOSTAT,²⁰ which includes emissions data for both agricultural and forestry sectors. This database includes country-level emissions estimates (basically country-specific activity data and Tier 1 emissions factors, as described in the followings sections) spanning 1961 to 2010. The included sectors and sub-sectors are:

- Agriculture
 - Enteric fermentation
 - Manure management
 - Rice cultivation
 - Synthetic fertilizers
 - Manure applied to soils
 - Manure left on pasture
 - Cultivated organic soils

¹⁷ See <http://www.docstoc.com/docs/24291611/IPCC-EFDB-User-Manual-part-1-version-20>

¹⁸ See <http://ebookbrowse.com/ipcc-efdb-pdf-d399449921>

¹⁹ See <http://www.ipcc-nggip.iges.or.jp/EFDB/main.php>

²⁰ See <http://faostat3.fao.org/home/index.html#DOWNLOAD>

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- Burning crop residues
- Forests and Cropland
 - Forest land
 - Crop land

The FAOSTAT database does not include two non-CO₂ emissions categories reported in IPCC reports, namely biomass burning and drained organic soils, because these categories require detailed spatial analysis beyond the scope of a simple Tier 1 approach and available input data from recognized and reliable scientific literature are sparse and uncertain.²¹

The FAOSTAT database includes country-specific activity data reported officially to FAO. These data are collected by member countries through their national agricultural statistical offices and through other entities.²² The GHG emissions factors employed in FAOSTAT,²³ however, are IPCC Tier 1 default factors, with the only exception being forestry, for which Tier 2 level emissions estimation methodologies are used. According to FAO, the deliberate use of mostly Tier 1 IPCC default factors in FAOSTAT is intended to bring coherence to emissions estimations and to allow for comparisons between countries and regions.²⁴ It is up to countries to decide if and how they want to move to Tier 2/3 levels. FAO, however, has calculated GHG emissions estimates by country using Tier 1 and Tier 2 (for forestry) methodologies, which will not match the emissions numbers from the National Communications developed by each country that may be based on higher tier, country-specific methods.

The 2006 IPCC Guidelines suggest that moving from Tier 1 to higher tiers could lead to a significant change in uncertainty of emissions factors (for example, the uncertainty in methane emissions factors for rice cultivation is as much as 60 percent). However, FAO points out that complex, landscape dynamic models that are used in Tier 2/Tier 3 estimation methodologies also carry uncertainty related to spatial and temporal aggregation schemes, as well as applicability ranges, for instance. FAO carried out an initial comparison of FAOSTAT emissions estimates (based on Tier 1 emission factors) with corresponding UNFCCC Annex 1 developed countries GHG emissions estimates and found small, usually statistically non-significant differences between the two sets of data. However, this analysis is not conclusive and requires further research.²⁵

FAO held a workshop on GHG emissions in Vietnam in October 2012 that included capacity building on the use of FAOSTAT, and has scheduled workshops for the Latin America region at the end of May 2013, and in Africa in the fall of 2013. FAO has started consulting with various agencies to collaborate on the quantification of emissions, including the Chinese Academy of Agricultural Sciences, with which the FAO is beginning a dialogue to share information on best practices, data techniques, and lessons learned.

An important challenge in developing higher tier CSEFs in the AFOLU sector is that in FAO's opinion, land use change and forestry sub-sectors present difficulties both in terms of collecting and applying reliable activity data (especially given the challenges in collecting adequate and accurate of land use data).²⁶

²¹ See http://iopscience.iop.org/1748-9326/8/1/015009/pdf/1748-9326_8_1_015009.pdf

²² See http://iopscience.iop.org/1748-9326/8/1/015009/pdf/1748-9326_8_1_015009.pdf

²³ Emissions factors can be downloaded from the 'download' section and be filtered for specific sectors, sub-sectors, gases, countries, years, etc.

²⁴ Personal communication with Dr. Francesco Tubiello on January 30, 2013.

²⁵ See http://iopscience.iop.org/1748-9326/8/1/015009/pdf/1748-9326_8_1_015009.pdf

²⁶ Personal communication with Dr. Francesco Tubiello on January 30, 2013.

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Thus, those charged with developing emissions factors in the AFOLU sector are likely also working on developing higher tier and more accurate and more detailed activity data. In consultations with FAO, FAO has suggested that priority areas of focus and improvement in terms of emissions estimates should be peatlands (tropical and non-tropical), deforestation, soils and rice cultivation.²⁷

Workshop on Greenhouse Gas Inventories in Asia (WGIA), Japan Ministry of Environment

Since 2003, the Greenhouse Gas Inventory Office of Japan has coordinated the annual Workshop of Greenhouse Gas Inventories in Asia (WGIA). The two-day workshop provides an opportunity for countries to share information and experiences related to developing and improving their national greenhouse gas inventories. Experts from international organizations, researchers, and government officials attend on behalf of WGIA member countries, including Cambodia, China, India, Indonesia, Japan, the Republic of Korea, Laos, Malaysia, Mongolia, Myanmar, Philippines, Singapore, Thailand, and Vietnam.²⁸ To date, WGIA's main activities have included:

- Identification of common issues and possible solutions to improve inventory quality;
- Sharing information on country activities and experiences to improve GHG inventories;
- Providing updates of the status of inventory development and improvement in each country;
- Establishment of a WGIA network platform to exchange information on climate change, mitigation measures, and GHG inventories;
- Publication of a WGIA activity report (with a specific focus on emission factor development in the region) entitled "Greenhouse Gas Inventory Development in Asia - Experiences from Workshops on Greenhouse Gas Inventories in Asia" in 2006;²⁹ and
- Publication of workshop proceedings, including executive summary, agenda, and presentations.³⁰

The workshop is the primary means by which WGIA improves the quality of GHG inventory and emission factor development in the region. The tenth (and most recent) workshop was held in July 2012 in Hanoi, Vietnam. There, over 130 experts from 13 of the 14 member countries and numerous international organizations attended and discussed eight main topics.

Workshop highlights included a "mutual learning" session where countries exchanged and reviewed inventories. Countries involved in this session concluded that developing a consolidated national inventory system and a methodology and documentation archive are vital to quality inventory development. Other workshop highlights included a discussion on Japan's climate change policy; discussion of mitigation options for GHG emissions in Vietnam; and presentations from India and Korea on their national inventories and the inventory improvements. WGIA's role is expanding from an in-situ information exchange to include email discussion, sector specific meetings, hands-on training, and mutual learning sessions, and the future proposal for the WGIA takes this ongoing expansion into account. Members also participated during the workshop in a hands-on training using the new IPCC inventory software and attended presentations on developments in the AFOLU sector.

²⁷ Personal communication with Dr. Francesco Tubiello on January 30, 2013.

²⁸ See <http://www.gio.nies.go.jp/wgia/pdf/wgia-leaflet-e.pdf>

²⁹ See <http://www.cger.nies.go.jp/publications/report/i067/i067.pdf>

³⁰ See <http://www.gio.nies.go.jp/wgia/pdf/wgia-leaflet-e.pdf>

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Outside of the workshops, WGIA hosts online discussions to facilitate the exchange of emission factors, makes available regional experts, and maintains a list of best practices in an online database. One of WGIA's core strategies to facilitate cooperation has been establishing a network platform to exchange information on climate change, GHG mitigation measures, and GHG inventories. A WGIA-Emission Factor Database was developed in 2009 and is accessible to member countries only.³¹ The database is composed of CSEFs provided by 10 WGIA countries: Cambodia, China, India, Indonesia, South Korea, Laos, Malaysia, Mongolia, Thailand, and Vietnam. The emission factors cover a variety of sectors, including energy, agriculture, industrial processes, land-use change and forestry, and waste.

Lowering Emissions in Asia's Forest (LEAF) Program

USAID/RDMA is supporting the LEAF program, a regional five-year, USD 20 million effort with the goal of "strengthening the capacity of target countries in Asia to achieve meaningful and sustained reductions in greenhouse gas emissions from the forestry-land use sector, thus allowing these countries to benefit from the emerging international Reducing Emissions from Deforestation and Forest Degradation (REDD+) framework".³² The LEAF program is collaborating with a diverse group of stakeholders, partners and regional organizations to implement and/or support sub-national interventions in six countries (Cambodia, Laos, Thailand, Vietnam, Papua New Guinea and Malaysia) and sharing lessons learned and best practices to scale-up innovation in and/or from potentially six other countries (Bangladesh, Bhutan, India, Indonesia, Nepal and the Philippines).³³ LEAF's activities center on regional information exchange and learning through three main processes: (a) applying international technical expertise to inform regional dialogue on developing REDD+ procedures and processes; (b) supporting regional bodies and mechanisms which themselves support information exchange and standardization across the region; and (c) functioning as a regional hub of expertise in relation to key regional issues.³⁴

LEAF is carrying out activities primarily at the sub-national level. One program activity involves the development of interim sub-national reference levels (a benchmark for quantification of net forestry emissions) through capacity building and training in select provinces in Vietnam and Laos, with additional programs planned to start soon in Papua New Guinea. The program is also conducting training on carbon stock assessment methodologies and development of forest carbon stratification maps.

LEAF has developed a number of tools and resources including the Terrestrial Carbon Measurement standard operating procedures (SOP) and the Terrestrial Carbon Assessment Toolkit. Toolkit modules include the Destructive Harvest Data Entry Tool, Manual Carbon Stock Calculation Tool, and Estimating Carbon Emissions Factors from Selective Logging Tool. The Estimating Carbon Emissions Factors from Selective Logging Tool, for example, allows for a bottom-up assessment of emissions based on specific characteristics of the trees and soil on a plot of land.

Although LEAF has not yet undertaken national or sub-national specific emission factor development, the program is planning to develop an SOP document on the development, use, and application of emissions factors for the forestry sector. LEAF's view is that forestry emission factors should be derived based on forest strata rather than species, because the former is a more feasible and cost-effective

³¹ See <http://www.gio.nies.go.jp/wgia/wg7/pdf/4.3.2.%20Junko%20Akagi.pdf>

³² See <http://www.leafasia.org/about-us>

³³ *Ibid.*

³⁴ *Ibid.*

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approach, and can cover much larger areas of land while streamlining data collection and emissions-estimation efforts.³⁵ Thus, forest level stratification is essential to developing higher tier emission factors, according to LEAF.

LEAF's priorities and areas of emission factor improvement are as follows:

- Improve methodologies of quantification of removals and emissions from degraded lands primarily for shifting cultivation usage activities and secondarily for selective logging and fuelwood collection activities. Emissions and removals from afforestation and reforestation are comparatively much better understood and there is already good existing literature on carbon accumulation rates for these activities.
- Reach consensus amongst program stakeholders on which forest strata need to be defined at the national and sub-national levels. This is essential to developing higher tier emission factors for forestry.
- Train national staff on how to undertake forest plot research to determine higher tier emission factors for forestry. While there has been a lot of attention recently on measurement reporting and verification (MRV) of emissions and removals and collecting accurate activity data, the development of data that can be used to develop emissions factors is just as important.
- Evaluate the quality of data, particularly around statistical sampling of data sets used. This is essential to formulating high quality emission factors.

2.3 Objectives of the Report

The goal of this report is to provide an objective analysis that recommends up to six specific emission factors on which to ultimately provide training and technical assistance to LEAD countries. The research team conducted four main activities to prepare this analysis.

1. Consulting with regional stakeholders and country experts to gather thoughts on emissions factors that are currently used in the 10 LEAD countries included in this report and views on which emission factors are their priorities for improvement.
2. Preparing a draft selection framework to guide the analysis and prioritization of emission factors for further development. This framework identified key factors for prioritizing emission factors (discussed in later sections of the report) and incorporated information from LEAD country National Communications.
3. Conducting the analysis by reviewing technical literature and stakeholder and in-country communications, and synthesizing the results of in-person consultations and discussions with regional experts.
4. Evaluating black carbon and other short-lived climate pollutants (SLCPs) and their likely impacts on climate change and estimates of emissions from LEAD countries.

2.4 Limitations

The stakeholder framework and in-country consultations involved 10 LEAD program countries. While the desk research included an examination of emission factor development efforts in these countries, this

³⁵ Personal communication with Peter Stephen of the LEAF Program on March 22nd, 2013.

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effort was limited to information gathered through publically available sources. The country consultations, while instrumental in gathering information and views first-hand from relevant experts and policy makers, were limited to a select group of individuals owing to time, budget, and availability constraints and did *not* cover emission factor development efforts in similar detail. Consequently, both the desk research and in-country consultations attempted to cover a broad array of existing efforts but were not meant to be exhaustive.

In addition because some of the estimates in NCs examined through the desk research are up to 20 years old, examining the inventory snapshot at the time of the NC does not necessarily provide the most current or accurate representation of a country's current issues. For example, the relative magnitudes of GHG emissions from different source categories may be greatly different now than it was 20 years ago. So for these countries the research team placed more focus on in-country communications to identify which emissions estimation methodologies could benefit from improvement.

3. IN-COUNTRY CONSULTATIONS

The research team conducted consultations with experts from 10 LEAD program countries: Bangladesh, Cambodia, India, Indonesia, Laos, Malaysia, Nepal, Philippines, Thailand, and Vietnam. Sector experts from each country for which consultations were conducted were identified based on the information in the recent NCs, the list of experts from the USEPA Southeast Asia Capacity Building (EPA SEA Phase II) project contact database, and list of experts identified through other consultations conducted under the LEAD program. Some consultations were conducted in-person during country visits by the research team or by LEAD country coordinators present in the country, while others were conducted over the telephone.

For these consultations, the research team interacted with technical experts and/or policy makers who have worked/are working on the national GHG inventory and who are closely involved in the estimation of emissions (i.e. working with emission factors and/or activity data). A summary of consultations for each country is provided in this section, which summarizes the current national GHG inventory situation, ongoing/planned improvements, and gaps and resource needs for development/improvement of country-specific emission factors. Table 3-1 provides a summary of GHG emissions by country and sector to provide context. Table 3-2 provides the priority emission factors identified for each LEAD program country for which consultations were conducted based on these expert consultations.

Table 3-1: Total Emissions by Country (Gg CO₂-eq.)

Country	Source	Inventory Year	Energy	Industry	Agriculture	Waste	LULUCF (Emissions)	LULUCF (Sinks)	Total ^a
Bangladesh	NC2	2005	38,645	2,913	36,051	14,762	22,534	-4,329	110,576
Cambodia	NC1	1994	9,655 ^b	50	10,560	273	46,943	-64,850	-7,024
India	NC2	2000	1,027,016	88,608	355,600	52,552	13,689	-236,257	1,301,208
Indonesia	NC2	2000	280,936	42,669	75,420	157,328	1,232,847	-296,794	1,492,406

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Laos	NC1	1990	930	-	5,697	240	17,310	-121,614	-97,437
Malaysia	NC2	2000	147,001	14,134	5,906	26,351	29,590	-249,784	-26,802
Nepal	NC1	1994	3,266	165	27,197	520	22,895	-14,778	39,265
Philippines	NC1	1994	98,528 ^b	10,603	33,130	7,094	68,197	-68,323	50,701
Thailand	NC2	2000	159,382	16,380	51,871	9,316	44,483	-52,374	229,058
Vietnam	NC2	2000	52,773	10,006	65,091	7,925	90,854	-75,749	150,900

^a Total includes emissions and sinks.^b Includes emissions from biomass.

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Table 3-2: Expressed Priority Needs for Country-Specific Emission Factors from National Consultations

<i>Source Category</i>	Bangladesh	Cambodia	India	Indonesia	Laos	Malaysia	Nepal	Philippines	Thailand	Vietnam	Total
CH ₄ emissions from rice cultivation	X	X			X				X	X	5
CH ₄ emissions from manure management	X		X						X	X	5
CO ₂ emissions from mobile combustion		X	X	X				X	X		5
CH ₄ emissions from mobile combustion		X	X	X				X	X		5
N ₂ O emissions from mobile combustion		X	X	X				X	X		5
CH ₄ emissions from enteric fermentation	X	X							X	X	4
CO ₂ emissions from coal Combustion	X					X			X	X	4
CO ₂ , CH ₄ , N ₂ O Emissions from other LULUCF categories, (CO ₂ removals from woody and forest biomass, CO ₂ from forest conversions to croplands for grasslands, CO ₂ from forest soils)			X	X	X				X		4
N ₂ O emissions from manure management	X		X						X		3
CO ₂ emissions from natural gas combustion	X					X			X		3
CO ₂ emissions from iron & steel production			X	X							2
CH ₄ emissions from iron & steel production			X	X							2
CO ₂ , CH ₄ , N ₂ O from other industrial processes including cement manufacture, electronics manufacture			X	X							2
CO ₂ , CH ₄ emissions from peatlands			X	X							2
Changes in soil carbon stock			X								1

NOT FOR DISTRIBUTION**DRAFT – JULY 2013****Bangladesh****Current Inventory Situation:**

Bangladesh submitted its NC2 to the UNFCCC in December 2012 and anticipates starting work on its BUR and NC3 submissions. Bangladesh's NC2 uses IPCC default (Tier 1) emission factors to estimate GHG emissions for most of the sources in their inventory. Regional emission factors were used in some cases. For example, for CH₄ emissions from enteric fermentation a regional emission factor from India's NC2 was used.

Ongoing/Planned Improvements:

No experts reported any current efforts to improve emission factors (i.e. to develop Tier 2 emission factors or Tier 3 methodologies). There was, however, an initial attempt to develop country-specific emission factors for agriculture, specifically for CH₄ emissions from livestock enteric fermentation and manure management, but that effort was not carried to completion. The EPA SEA II project is providing capacity-building support for GHG inventory improvement in Bangladesh, but currently there are no plans to provide support for emission factor improvement in Bangladesh.

Gaps and Resource Needs:

The Department of Environment emphasized the need for improved activity data for all sectors (especially energy and agriculture) as a higher priority than emission factor improvement. During the consultations, the energy and agriculture sectors were identified as priority areas for the development of country-specific emission factors. Bangladesh imports a majority of the coal used in the country and does not have country-specific emission factors for the variety of coal being imported. Stationary combustion in the energy sector primarily relies on natural gas as a fuel, and as a result country-specific emission factor for stationary combustion for natural gas is also a priority.

Cambodia**Current Inventory Situation:**

Cambodia submitted its NC1 to the UNFCCC in October 2002 and is now working on its NC2 and BUR. Cambodia's NC1 uses entirely IPCC default (Tier 1) emission factors to estimate emissions for the GHG inventory.

Ongoing/Planned Improvements:

No experts reported any currently planned activities to develop country-specific emission factors.

Gaps and Resource Needs:

During the consultations, emission factors for the stationary combustion in the energy sector, transport (mobile combustion) in the energy sector, and livestock (enteric fermentation and manure management) in the agriculture sector, were identified as priority areas. For mobile combustion-related emissions, characterization of emission factors by vehicle type has been quite challenging due to the diversity of the vehicle mix and the large number of second-hand vehicles used for road transport. This was identified as an area for improvement of emission factors.

India

NOT FOR DISTRIBUTION**DRAFT – JULY 2013****Current Inventory Situation:**

India submitted its NC2 in May 2012 and anticipates starting work on its BUR and NC3. India's NC2 and the 2007 national inventory report (INCCA 2010) used a combination of IPCC default (Tier 1) emission factors and Tier 2 emission factors. Country-specific emission factors were used for CO₂ emissions from coal combustion, fugitive CH₄ emissions from coal mining, N₂O emissions from nitric acid production, energy (fuel combustion) and Industrial Processes and Product Use (IPPU) (raw material) CO₂ emissions from cement production, CH₄ emissions from rice cultivation, CH₄ emissions from enteric fermentation in livestock, N₂O emissions from soils, and CH₄ emissions from municipal solid waste management, among others.

Ongoing/Planned Improvements:

The Central Road Research Institute (CRRRI) is conducting some work for the improvement of country-specific emission factors for transport (mobile combustion). In addition, efforts are being made to improve the existing Tier 2 emission estimates for cement production by the Confederation of Indian Industries (CII) and possibly to develop Tier 3 estimation methodologies for cement production by the cement industry.

Gaps and Resource Needs:

India has country-specific emission factors for coal combustion for indigenous varieties of coal, but a key gap is the lack of information on composition and use of imported coal. Once obtained, these data can be used to improve the existing country-specific emission factor for coal combustion. Other priority areas also include development of country-specific emission factors for LULUCF sources/sinks, IPPU, and transport (mobile combustion). For LULUCF, experts emphasized a need for development of emission factors for perennial biomass, croplands, grasslands, wetlands and carbon stock changes in plantations, as well as secondary and disturbed forests.

For IPPU, priority areas include emissions of fluorinated gases from fast growing industries such as manufacturing of electronic goods like TVs and computers. Other priority areas are improvement of existing Tier 2 emission estimates, e.g. for cement production. Estimating energy and IPPU emissions (even using Tier 1 methods) from small and medium industrial enterprises is a challenge due to lack of good quality activity data, the dispersed nature of these organizations, and lack of process-related information. Thus, there is a need to improve data quality for this category of industries.

In addition, since India has already developed several country-specific emission factors, these emission factors and country knowledge can be used to build capacity of other countries in the region. Some countries are already using emission factors from other countries. For example, Bangladesh and Nepal use emission factors from India for CH₄ from enteric fermentation for their NC2. There is an opportunity for Indian experts to share their best practices and lessons learned from their efforts on emission factor development. There is also scope for refining Indian emission factors to develop regional emission factor for source/sinks where this may be relevant (e.g., agriculture sector).

Indonesia**Current Inventory Situation:**

Indonesia submitted its NC2 to the UNFCCC in January 2011 (with a subsequent update in January 2012) and anticipates starting work on its BUR and NC3. Indonesia's NC2 mainly used IPCC default (Tier 1)

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emission factors and some country-specific (Tier 2) emission factors, such as for CH₄ emissions from rice cultivation and emissions from LULUCF categories. For the energy sector, electrical grid emission factors have been successfully developed at the provincial level and were used in NC2. Country-specific emission factors are also being used for IPPU CO₂ emissions from cement and ammonia production.

Ongoing/Planned Improvements:

Efforts are underway to develop country-specific emission factors for categories within the agriculture sector (other than CH₄ emissions from rice cultivation), peatlands, and the energy sector including stationary and mobile combustion. Data collection activities are being carried out to improve the current livestock data. Country-specific emission factors are being explored for enteric fermentation and manure management emissions from cattle, buffalo, and other livestock.

One of the major challenges has been to reconcile livestock population data from the Ministry of Agriculture and the Department of Statistics. Developing emissions estimates for peatlands has also been a challenge due to the high uncertainty associated with activity data for fire management, drained peatlands, and water level management. The Ministry of Agriculture (through the National Research Consortium for Climate Variability and Climate Change) has conducted studies to develop emissions factors from peatlands under different usage scenarios in Central Kalimantan.³⁶ The state Ministry of Environment is conducting a pilot study on peatland management, including calculation of GHG emissions from peatlands in West Kalimantan and Riau Province.³⁷

Meanwhile, Indonesia's National Development Planning Agency (BAPPENAS) has commissioned a detailed analysis on peat land emission and projection as well as mitigation strategies. The analysis is undertaken by a multi-disciplinary team of Indonesian scientists, economists, and legal specialists. Land use change and forestry emissions are also being calculated using Tier 2 methods at the provincial level. The Ministry of Forestry (MoF) is improving the emission sink factors from forests and emission factors from fire (both in mineral soils and peatland). The program is being undertaken through the Indonesian National Carbon Accounting System (INCAS) and other relevant research programs under the MoF and partners. Additionally, Gesellschaft für Internationale Zusammenarbeit (GIZ) is currently providing support for the development of mobile combustion emission factors in five provinces.

Gaps and Resource Needs:

The priority areas for Indonesia are development of country-specific emissions factors for livestock (specifically, enteric fermentation and manure management); drained peatlands, oil palm plantations on peatlands and the use of fertilizers on peatlands; and changes in soil carbon stock. Experts also identified the need to improve the specificity of emission factors (and quality of the activity data) for the iron and steel industries. For example, the default emission factors do not completely reflect the characteristics of the Indonesian steel industry.

Laos

³⁶ Indonesia SNC.

³⁷ *Ibid*

NOT FOR DISTRIBUTION**DRAFT – JULY 2013****Current Inventory Situation:**

Laos submitted its NC1 to the UNFCCC in November 2000 and is now working on its NC2 and anticipates submitting a BUR. The NC1 for Laos included IPCC default (Tier 1) emission factors to estimate emission for all sectors included in the GHG inventory and highlighted the lack of capacity to develop country-specific emission factors.

Ongoing/Planned Improvements:

USAID's LEAD and LEAF programs are conducting studies for the development emission factors for the LULUCF sector. LEAD is undertaking emissions mapping for forest land and conversions at the provincial level, while LEAF is planning to support work that develops allometric equations and data results.

Gaps and Resource Needs:

Emission from rice cultivation and the LULUCF sector were identified as priority areas for the development of country-specific emission factors. Laos is also working towards the development of Nationally Appropriate Mitigation Actions (NAMAs) for which the country-specific emission factors would be very useful.

Malaysia**Current Inventory Situation:**

Malaysia submitted its NC2 to the UNFCCC in April 2011 and anticipates starting work on its BUR and NC3. The NC2 used IPCC default (Tier 1) emission factors to estimate GHG emissions for all source categories. Many industries, especially oil and natural gas production, have emphasized the need for development of country-specific emission factors based on the GHG accounting methods adopted by the industry.

Ongoing/Planned Improvements:

Currently no activities are underway that focus on the development of country-specific emission factors.

Gaps and Resource Needs:

The energy sector (particularly oil and natural gas industries) is a priority sector for the development of country-specific emission factors. However, since default emission factors are being used to estimate all emissions, experts expressed interest in development of country-specific emission factors for all sources/sinks.

Nepal**Current Inventory Situation:**

Nepal submitted its NC1 to the UNFCCC on September 2004 and anticipates starting work on its BUR and NC2. Nepal's NC2 has been drafted and the GHG Inventory chapter has been completed. The Nepal team is presently completing the mitigation analysis section before submitting the NC2. With regard to quality assurance/quality control (QA/QC), there is a documented third party review of the inventory. Some experts from national ministries and some external experts were part of the review. The review process is documented for internal use but might not be included in the actual NC2 report. Work is also underway in Nepal on Low Carbon Emission Development Plans that are financed by the United Kingdom's Department for International Development (DFID). Each ministry has an environmental cell that is working in technical working groups to provide inputs to these plans. The experts emphasize that

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building expertise within the government is difficult as there are staff transfers every 1-2 years. However, agriculture and forestry sector specialists are expected to remain within their respective ministries.

Ongoing/Planned Improvements:

No efforts are underway to develop country-specific emission factors. There has been some discussion about developing emission factors for biomass for cook stoves, as it covers 80 percent of fuel in rural areas. Development of country-specific emission factors for mobile combustion has also been challenging. In many cases, GHG emissions are estimated using emission factors from other parts of the region, such as livestock from India. This can be problematic, though. For example, livestock feeding habits are different across countries, thus adversely affecting estimate accuracy.

Gaps and Resource Needs:

The priority sectors identified for Nepal are LULUCF and agriculture as emission estimation is challenging for these sectors. Enteric fermentation is a key category for which emission factor improvement and activity data improvement are needed. The inventory team highlighted a need for both training for sector experts and accredited laboratories for research in emission factor development. Lack of reliable activity data was also identified as an issue for all LULUCF categories. The inventory team highlighted a need for assistance in disaggregating the energy sector emissions into further categories. The team felt comfortable in its reference approach estimates but less so for the sectoral approach estimates because reliable bottom-up data was unavailable for energy consumption across sectors.

Philippines

Current Inventory Situation:

The Philippines is currently conducting an internal review of the NC2 and is beginning to develop its BUR and NC3. The NC1 was developed by an eight-person in-house team, while contracted consultants developed the NC2. The NC2 included emission estimates that primarily use IPCC default (Tier I) emission factors and in some cases use Tier 2 emission factors. Tier 2 emission factors were used for CH₄ from rice cultivation, CH₄ from solid waste disposal, CO₂ removals from woody biomass, and CO₂ emission from changes in land use and forests.

Ongoing/Planned Improvements:

A new inventory system and centralized data collection process are under development and the Department of Environment and Natural Resources (DENR) is improving the statistics database. A reference manual is also in development and includes information on activity data, emission factors, and documentations. These improvements are building upon the methodologies used in the NC2. However, currently there is no mandate or executive order to develop/improve emission factors and there are several gaps in emission factors used by the Philippines.

Emission factors for the transport and power sector are high priorities for the Philippines. The Department of Energy (DOE) conducted research for emission factor development for the energy sector that included testing heating values and calorific values and testing coal to determine anthracite content. Experts from the Philippines attended an emissions factor training in 2011 sponsored by the Japanese Automotive Society but language was a major barrier. Furthermore, experts indicated that JICA developed fuel emission factors for buses and cars without involvement from the Philippines or capacity building activities for the country experts. The Philippines is now looking to further develop emission factors for all modes of transportation.

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Developing emission factors for the LULUCF sector is also a high priority given the large uncertainty associated with estimates from this sector, particularly with regards to grasslands and brush lands. There are approximately 9-10 billion hectares of grasslands and brush lands in the Philippines. The University of the Philippines has made some progress in improving emissions estimates for this land mass but coordination between the forest mapping bureau and the mapping resource group presents difficulties.

Gaps/Resource Needs:

Experts emphasized that the Philippines needs grants or donor assistance to develop country-specific emission factors. For emissions factor development, the Philippines could use technical assistance and training from the LEAD program to learn how to develop country specific emission factors across sectors. The Philippines is aiming to develop country-specific emission factors for agriculture, transport, and LULUCF sectors. Within the forestry sector, experts mentioned the need to implement extensive field sampling to get collect better activity data specifically, assistance related to timber harvesting, ship in cultivation, forest burning, and forest degradation. The DOE already has power sector emissions factors through the Institute for Global Environmental Strategies (IGES), which are entity/scope 2 level; however, the DOE could use assistance to improve the integration of GHG computation and emission factors into models such as LEAP. The DOE is also looking for assistance collecting regional data surveys and data on renewable energy, biomass, and fuel wood. Additionally, the Philippines needs assistance developing a data management system to find, gather, and store quality datasets.

Thailand**Current Inventory Situation:**

Thailand submitted its NC2 to the UNCCCC in March 2011 and is beginning work on the NC3, which will focus on transitioning to the 2006 IPCC guidelines. Thailand's NC2 used some country-specific emission factors such as for N₂O emissions from animal waste management, GHG emissions from rice cultivation, forest management, and waste management.

Ongoing/Planned Improvements:

Experts mentioned that efforts had recently begun on development of emission factors for fossil fuels combustion and waste water treatment.

Gaps and Resource Needs:

Based on the consultations, the developers and compilers of the national communications for Thailand identified factors for emissions from the energy sector, rice cultivation, enteric fermentation, manure management, and LULUCF categories as priority areas.

Vietnam**Current Inventory Situation:**

Vietnam submitted its NC2 to the UNFCCC in March 2010 and anticipates starting work on its NC3 and BUR. Nearly all GHG emissions estimates for Vietnam to date have relied on IPCC default (Tier 1) emission factors. A combination of country-specific and default emission factor was used for CH₄ emissions from rice cultivation.

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Ongoing/Planned Improvements:

JICA – through WGIA – is currently funding a project to improve the Vietnam national inventory, including development of country-specific emission factors. Efforts have been undertaken to develop emission factors for CH₄ emissions from rice cultivation, CO₂ emissions from coal combustion, and fugitive CH₄ emissions from coal mining.

Gaps and Resource Needs:

According to national experts, the CH₄ emission factor for rice cultivation could be refined using supplemental measurements at specific ecological areas. However, the priority emission factors for further development include emissions from coal combustion, and emissions from livestock (enteric fermentation and manure management) given their contribution to total emissions. IGES is currently providing capacity building support to develop market mechanisms to combat climate changes. As part of the activities included in the MOU signed for this capacity building support, IGES and Vietnam's Ministry of Natural Resources and Environment (MONRE) will develop a CO₂ emission factor for the national electricity system. IGES also expressed interest in collaborating with the LEAD program on emission factor development.

4. SELECTION FRAMEWORK

The study team developed a selection framework in order to conduct an objective evaluation of emissions factors used by the LEAD countries and prioritization of certain emission factors for further development. The purpose of this framework was to enable the study team to a) determine relevant parameters of interest for which data was collected, and b) allow comparisons among countries in a consistent and streamlined manner.

The framework has two main components:

- Data that have been collected, assessed and populated in response to each of the quantitative and qualitative parameters at a sector (and in some cases, sub-sector) level for each of the LEAD countries.
- Weighting factors (developed by the study team) in order to assign scores to each quantitative and qualitative data point per parameter in order to help determine objectively which sectors/sub-sectors for each country exhibit weakness and require improvement for a higher tier emissions factor. The study team developed these weighting factors so that they reflect the range of possibilities across each emission factor from a sector/sub-sector specific perspective. High scores reflect the need for improvement (i.e. Tier 1 default factors are given a higher score than Tier 2 factors or Tier 3 methodologies) and/or importance for that sector (a sector that has a high national share of emissions has a higher score than a sector with a relatively lower share of emissions).

The main components of the framework are as follows:

- **Key category analysis (KCA).** This section indicates the percentage share of a sub-sector's emissions to that of a total sectoral level (if available) and at a total national level. The main purpose of this section is to provide context of the relative importance of a sector in terms of emissions contribution at various scales. Historic emission data taken from each country's most recent NC was used for the KCA; any projections of future emissions were not included.

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Projections of future emissions are not available for all countries and some of these projections were made several years ago thus were not included in this analysis. As part of the in-country consultation process, local experts were asked about anticipated key category and this was taken into account in the evaluation.

- **Emissions factor analysis.** This section lists at a sub-sector or sector level (for whichever level more granular data is available) not only the emission factors used, but also the tier they represent, if the emission factor is a default factor, a subjective assessment of the ease in deriving the emission factor (particularly for Tier 2 and 3 factors that may have been developed and used by the countries in question), and the uncertainty associated with the emission factor currently being used. The objective of this section is to provide a current status of emission factors used in sectors/sub-sectors with some key associated parameters.

The criteria that were scored for this emission factor evaluation are: 1) the source's contribution to total national emissions; 2) the source's contribution to a given sector's emissions; 3) the relative ease of deriving emission factors for that source or sector, assessed in a subjective manner; 4) the current methodology and emission factors used to estimate emissions for the source; and 5) the level of uncertainty for the emission factors that are currently being used. The weights for "percentage share of total national emissions" and "current tier and emission factors used" have a higher range of scores to account for the higher relative importance of these criteria. This scoring system was designed to allow for a relative comparison across the 10 LEAD countries using a common evaluation system.

The ranges used in the scores for "percentage share of total national emissions" (i.e., 5 percent increments from 0 to 25) and for "percentage share of sector emissions (i.e., 33 percent increments from 0 to 100) were devised this way in order to account for these parameters across the 10 LEAD countries studied for this report in a realistic and common manner; in other words, these fractions were representative of emissions both between and among countries, hence facilitating comparison of data for these parameters in a streamlined manner.

ICF applied expert judgment and past experience in devising the scoring scheme for the "ease of emission factor development" parameter, with the thinking that it is relatively easier to derive Tier 2 and 3 EFs in the energy sector (hence a score of 1), than it would be for the agriculture, land use and fugitive emissions sectors (a score of 3) given that the development of these factors would be more complex, have a higher degree of uncertainty, and require a greater level of effort to move to a Tier 2 or 3 factor. If information is unknown for a criterion, a moderate score is assigned to avoid a bias towards sources that have little published information available. Table 4-1 provides an overview of the weighted scoring system that was applied to the selection framework.

Table 4-1: Emission Factor Framework Criteria and Scoring System

Criteria	Scoring	
Percentage share of total national emissions	2	Source accounts for 0 to 5 percent of total national emissions
	4	Source accounts for 5 to 10 percent of total national emissions
	6	Source accounts for 10 to 15 percent of total national emissions
	8	Source accounts for 15 to 20 percent of total national emissions
	10	Source accounts for 20 to 25 percent of total national emissions
	12	Source accounts for more than 25 percent of total national emissions

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Percentage share of sector	Source accounts for up to 33 percent of a sector's total emissions	
	2	Source accounts for 33 to 66 percent of a sector's total emissions
	3	Source accounts for 66 to 100 percent of a sector's total emissions
Ease of emission factor development	1	Relatively Easy (e.g., stationary combustion energy sector)
	2	Medium (e.g., industry (IPPU), mobile combustion, waste)
	3	Complex (e.g., agriculture, LULUCF, fugitive emissions from oil and natural gas)
Current tier and emission factors used	1	Tier 3, country-specific, local emission estimation methodology, or CEMS (continuous emissions monitoring system)
	3	Tier 2, country-specific or mix of Tier 1 and Tier 2 emission factors
		No information available in the NCs concerning tiers or estimation methods
	5	Tier 1, default emission factors
Level of uncertainty	1	Low
	2	Medium
		Unknown
	3	High or similar to the IPCC Tier 1 emission factors

After completing this framework for each country, a series of scores were generated for each sector/sub-sector. High scores indicate priority areas and potential areas of improvement.

Four key qualitative elements were reviewed for each country through the study team's collection of available information and judgment. This qualitative analysis is summarized in narrative form as part of each country write-up in the section that follows and considers the following four elements, as relevant to each country:

- *Potential of emission factor to be used by other countries with similar conditions:* applicability of the emission factor to other countries in the region, particularly those that have developed Tier 2 factors or Tier 3 methodologies for individual sectors and others that could benefit from the factor or the approach used to develop a higher tier factor.
- *Relevance of emission factor to GHG mitigation programs/actions under consideration in LEAD countries:* this refers to the broader GHG and climate change policy context (including internal regulations, laws and programs, as well as external obligations and aspirations), such as national GHG reduction plans, green growth strategies, current/future energy and carbon trading schemes, among a range of policies.
- *Studies already underway to improve the emission factor (i.e. by whom, status of efforts, future*

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plans, etc.): this refers to both domestic and internationally-funded efforts that might already be underway to develop higher tier emission factors for that sector in that country.

- *Consideration of other existing or planned efforts to improve emission factor*: this refers to other efforts underway/planned (e.g., potential technological improvements) to improve the emission factor that may not be captured in the other parameters.

At a broader level, results of national government and global/regional development partner consultations were then transposed onto these scores to provide a more nuanced process with country-specific inputs as well as input from global/regional partners. The combined results of these complementary efforts are provided in Section 6.

4.1 Selection Framework Results

Table 3 provides a summary of emission factor priorities for all LEAD countries based on a weighted score. The score takes into account each source's contribution to national and sector emissions, the ease of developing higher-tier emission factors for that source, the current methodology and emission factors being used to estimate emissions, and the uncertainty associated with the emission factors being used. The sources with the highest scores for each country have been noted.

In total, 24 source categories were identified as priorities across the ten countries that are included in this report. CO₂ removal from changes in woody and forest biomass is a high scoring source for seven of the ten countries. Carbon dioxide emissions from forestland converted to grassland is a high scoring source category for half of the countries considered. CH₄ emissions from rice cultivation, CO₂ emissions from energy sector stationary combustion, N₂O emissions from management of agricultural soils, and CO₂ emissions from mobile combustion (transport) were priorities for emission factor improvement for four countries each. The remaining 18 source categories featured as a priority for three or fewer countries.

Detailed analyses of the key categories, emission factors, and the country-specific frameworks are provided in the following section for each of the 10 countries.

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Table 4-2: Summary of Highest Priority Emission Factors for Improvement Identified in Selection Framework

Source Category	Bangladesh	Cambodia	India	Indonesia	Laos	Malaysia	Nepal	Philippines	Thailand	Vietnam	Total
CO ₂ removals: changes forest and other woody biomass	X	X		X	X		X	X		X	7
CO ₂ emissions: forest and grassland conversion	X			X		X			X	X	5
CH ₄ emissions: rice cultivation		X	X		X		X			X	5
CO ₂ emissions: energy sector (stationary combustion)	X				X	X			X		4
N ₂ O emissions: agricultural soils		X	X				X		X		4
CO ₂ emissions: mobile combustion			X			X		X	X		4
CO ₂ emissions: manufacturing and construction (stationary combustion)	X					X			X		3
CO ₂ emissions/removals: forest & land use change		X			X			X			3
CH ₄ emissions: enteric fermentation		X					X		X		3
CH ₄ emissions: solid waste disposal			X			X				X	3
CO ₂ emissions: cement production								X	X	X	3
CH ₄ emissions: industrial waste water management			X	X							2
CO ₂ emissions/removals: forest soils				X						X	2
CO ₂ emissions: ammonia production	X										1
CO ₂ emissions: electricity generation			X								1
CO ₂ emissions: residential energy (stationary combustion)			X								1
CO ₂ emissions: limestone/ dolomite production			X								1
CO ₂ emissions: "other" sectors				X							1
CO ₂ : above ground decay (LULUCF)					X						1
CO ₂ emissions: forestland and cropland conversion							X				1
CO ₂ emissions: biomass combustion								X			1
CO ₂ emissions: iron and steel production								X			1
N ₂ O emissions: manure management								X			1

Bangladesh

Bangladesh submitted its NC2 to the UNFCCC in December 2012 that included a GHG inventory for the year 2005. Of the top 10 key categories in Bangladesh, five categories are agricultural sources, including N₂O emissions from manure management, CO₂ emissions from soil, CH₄ emissions from enteric fermentation, CH₄ emissions from rice cultivation, and CH₄ emissions from manure management. Four are energy sources (CO₂ emissions from energy industries, CO₂ emissions from manufacturing and construction, CO₂ emissions from other stationary sources, and CO₂ emissions from road transportation), and one is waste (CO₂ emissions from incineration and open burning of waste). These three sectors are significant contributors to national GHG emissions and are primarily estimated using Tier 1 methodologies, with some expert judgment and regional factors incorporated for agricultural sources.

The source with the largest contribution to national emissions is N₂O emissions from manure management, accounting for 16 percent of total emissions in 2005. This source was not estimated in the NC1 and limited historical emissions data are available for this source. Emission factors for manure management for cattle, buffalo, goats, sheep, and poultry are a combination of IPCC default values and expert judgment. Emission factors, correction factors, and activity data for this sector appear to be estimates based on expert judgment and the uncertainty of these estimates is not clearly defined in the national communications.

Carbon dioxide from fossil fuel combustion for energy industries (primarily electricity generation) and stationary combustion for manufacturing accounts for 10 and 9 percent of total national emissions, respectively. Carbon dioxide emissions from the energy sector have grown significantly since the NC1 and are projected to grow 6.4 percent annually between 2005 and 2030.³⁸ The emission factors used for this sector are IPCC default values and have not been adjusted by experts to account for regional variations in the composition of fossil fuels combusted.

Methane from enteric fermentation, which accounts for eight percent of total national emissions, is estimated using country-specific emission factors from India's NC2 that are adjusted based on the comparative body weight of Bangladeshi livestock compared to Indian livestock. The uncertainty of these adjusted emission factors is unknown. The activity data used to estimate enteric fermentation emissions from cattle is extrapolated from Bangladesh cattle population data from 1983 and 1984.

Bangladesh primarily uses Tier 1 default factors from IPCC for estimating emissions in the NC2. The Department of Environment (DoE) has stated that they do not have the capacity to develop Tier 2 emission factors or Tier 3 methodologies at this time. The DoE has previously attempted to refine emission factors related to livestock enteric fermentation and manure management but this initiative was not completed. The DoE identified agriculture and energy as the highest priority sectors for any future emission factor development.

Table 4-3 summarizes the key source categories in Bangladesh and provides an evaluation of emission factor priorities. Based on the weighted scores, CO₂ emissions from stationary combustion in energy industries (electricity generation), CO₂ emissions from stationary combustion in manufacturing industries and construction, and CO₂ emissions from ammonia production are the priority sectors for

³⁸ Projections from Section 3.10 of the NC2.

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emission factors improvement. These three sources account for 21 percent of total emissions and are estimated using Tier 1 methodologies. Carbon dioxide emissions from agricultural soils and from forest land converted to grassland, and CO₂ removals from changes in woody and forest biomass are also sectors with high scores that could be prioritized for emission factor improvement.

The benefits of CSEFs extend beyond having a more accurate national inventory. Bangladesh's Climate Change Strategy and Action Plan (CCSAP) lists a number of mitigation actions, all of which could be used as baselines and measured in the future with more accuracy if improved emission factors were developed and applied. Given that other countries such as India and Thailand are already facing the issue of how to account for imported fuels (particularly coal) in the development of country-specific factors, the potential for these countries to share lessons and ideas in this sector could be synergistic.

While the EPA SEA II project and other USAID projects (e.g., Integrated Protected Area Co-Management (IPAC), Catalyzing Clean Energy in Bangladesh (CCEB)) are not intending to develop country-specific emission factors, coordination with these USG programs as well as other donor-funded efforts could help to ensure that the most appropriate individuals are trained in the development of emission factors and conversely, LEAD could pursue an approach in tandem with these partners to develop selected priority emission factors.

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Table 4-3: Emission Factor Framework for Bangladesh

Source Category (level)	Sector	Gas	Emissions Estimate (Gg of CO ₂ e-eq.)	% Share of Total National Emissions		% Share of Sector Emissions		Ease of Moving to a Higher Tier Emission Factor		Tier and Emission Factor		Uncertainty with Emission Factor		Total Weight
				Value : x%	Weight Factor	Value : x%	Weight Factor	Description of EF	Weight Factor	Description	Weight Factor	Value e	Weight Factor	
Manure management	Agriculture	N ₂ O	20,974.60	16%	6	32%	1	IPCC default emission factors and/or judgment by experts	3	Tier 1/2 mix of default IPCC emission factors and local emission factors used.	5	N/A	2	14
Agricultural soils	Agriculture	CO ₂	17,582.40	13%	6	27%	1	Not described in NC2.	2	Not described in NC2.	3	N/A	2	14
Incineration and open burning of waste	Waste	CH ₄	13,042.68	10%	4	88%	3	Not described in NC2.	2	Tier 1; default IPCC emission factors used.	3	N/A	2	12
Energy industries ³⁹ (stationary combustion)	Energy	CO ₂	12,780.00	10%	4	33%	1	IPCC default emission and conversion factors used.	1	Tier 1; default IPCC emission factors used.	5	5%	2	12
Manufacturing industries and construction (stationary combustion)	Energy	CO ₂	11,276.00	9%	4	29%	1	IPCC default emission and conversion factors used.	1	Tier 1; default IPCC emission factors used.	5	5%	2	12
Enteric fermentation	Agriculture	CH ₄	10,356.36	8%	4	16%	1	Indian CSEFs adjusted based on livestock body weights and applied to Bangladesh.	3	Tier 2; regional emission factors used.	1	N/A	2	8
Manure management	Agriculture	CH ₄	8,990.52	7%	4	14%	1	Estimates of biogas production are based on local conditions.	3	Tier 1/2; mix of IPCC default and local emission factors.	3	N/A	2	10

³⁹ This primarily refers to electricity generation.

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Rice cultivations	Agriculture	CH ₄	7,873.53	6%	4	12%	1	Average seasonally integrated emission factor value taken from Indian studies.	3	Tier 2; regional emission factors used.	1	N/A	2	8
Other sectors (stationary combustion)	Energy	CO ₂	6,938.00	5%	4	18%	1	IPCC default emission and conversion factors used.	1	Tier 1; default IPCC emission factors used.	5	10%	2	12
Road transportation (mobile combustion)	Energy	CO ₂	5,500.00	4%	2	14%	1	IPCC default emission and conversion factors used.	2	Tier 1; default IPCC emission factors used.	5	5%	2	11
Forest and cropland conversion (emissions)	LULUCF	CO ₂	4,951.91	4%	2	53%	2	IPCC emission factors applied using Worksheet 5-2 on Forest and Grassland Conversion.	3	Tier 1; default IPCC emission factors used.	5	N/A	2	11
Forest land remaining forest land (removals)	LULUCF	CO ₂	(4,328.78)	3%	2	47%	2	Base data on forest products and harvesting area data taken from the Department of Forests.	3	Tier 1; default IPCC emission factors used.	5	N/A	2	11
Ammonia Production	IPPU	CO ₂	2,830.00	2%	2	97%	3	Ammonia production method (activity data) rather than natural gas consumption data was used to calculate emissions.	2	Tier 1; default IPCC emission factors used.	5	N/A	2	12

N/A: Not available

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Cambodia

Cambodia submitted its NC1 in 2002 that includes a national GHG inventory for 1994. Emissions were estimated using Tier 1 methodologies, relying primarily on IPCC default Tier 1 emission factors. There were six key categories identified in Cambodia's NC1, with the top two key categories from LULUCF, including CO₂ removals from changes in forest and woody biomass and CO₂ emissions from forest and land use change. LULUCF dominates Cambodia's GHG emissions and removals. Changes in forest and woody biomass sequestered nearly 65,000 gigagrams of carbon dioxide equivalent (Gg CO₂-eq.) in 1994 and forest and land use change resulted in approximately 45,200 Gg CO₂-eq. By comparison, the remaining key categories (biomass combustion, enteric fermentation, rice cultivation, and agricultural soils) collectively resulted in 16,560 Gg CO₂-eq. of emissions in 1994.

Since 1994, Tier 2 emission factors have been developed for the acacia forests that represent just one of many forest types in Cambodia.⁴⁰ Given that LULUCF accounts for 83 percent of total emissions for Cambodia, additional research is needed to develop emission factors for additional forest types. Cambodia has identified the agriculture (livestock enteric fermentation and manure management) and energy (stationary and mobile combustion) sectors as priorities for emission factor refinement.

Apart from LULUCF emissions, domestic food intake for animals needs to be examined and defined in order to develop emission factors for enteric fermentation and manure management. For stationary combustion in the energy sector, there is a need to develop an energy balance in order to reconcile top-down and bottom-up estimates.⁴¹ For mobile combustion, Cambodia identified many types of vehicles that would require different emission factors that would be needed for developing accurate emissions estimates. Energy sector emissions (including stationary and mobile combustion) have been identified as a priority for emission factor development by the country in expert consultations.⁴²

Table 4-4 presents a summary of the key source categories for Cambodia. According to the weighted scores, the highest priority sectors for emission factor improvement are CO₂ emissions/removals from forest and land use change, as well as CO₂ emissions/removals from changes in forest and woody biomass. These two LULUCF sectors are considered the highest priority because of the significance of these sectors' contribution to national emissions. Emissions from energy (stationary and mobile combustion) and agriculture (CH₄ emissions from enteric fermentation, CH₄ emissions from rice cultivation, and N₂O emissions from agricultural soils) are secondary priorities for emission factor improvement.

The benefits of CSEFs could extend beyond the national inventory to broader efforts in the country including the Green Growth Roadmap (GGR). Although the GGR has yet to reach the implementation phase, the development of more country-specific emission factors could help to obtain a more accurate picture for both baselining and future mitigation actions when implementation of the GGR is fully underway.

Coordination with other development programs such as the EPA SEA II project and the USAID LEAF program could help to ensure that the most appropriate individuals are trained in the development of

⁴⁰ Expert consultations with Kamal Uy, February 28, 2013.

⁴¹ *Ibid.*

⁴² *Ibid.*

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emission factors (particularly in land use change and forestry sectors). Furthermore, REDD efforts in the country (outside of the EPA SEA II and USAID LEAF projects) may also benefit from having more robust CSEFs in the LULUCF sector.

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Table 4-4: Emission Framework for Cambodia

Source Category (level)	Sector	Gas	Emissions Estimate (gg of CO ₂ e- eq.)	% Share of Total National Emissions		% Share of Sector Emissions		Ease of Moving to a Higher Tier Emission Factor		Tier and Emission Factor		Uncertainty with Emission Factor		Total Weight
				Value: x%	Weight Factor	Value: x%	Weight Factor	Descriptio n of EF	Weight t Factor	Descriptio n of EF	Weight t Factor	Value	Weight Factor	
Changes in forest and other woody biomass (removals)	LULUCF	CO ₂	(64,850.23)	49%	12	59%	2	IPCC default emission factors or CSEFs from Thailand, Philippines, or Indonesia were applied.	3	Tier 1; default IPCC emission factors used.	5	N/A	2	24
Forest and land use change (emissions)	LULUCF	CO ₂	45,214.27	34%	12	41%	2	IPCC default emission factors or CSEFs from Thailand, Philippines, or Indonesia were applied.	3	Tier 1; default IPCC emission factors used.	5	N/A	2	24
Biomass combustion(stationar y combustion)	Energy	CO ₂	7,773.53	6%	4	81%	3	IPCC default emission factors or CSEFs from Thailand, Philippines, or Indonesia were applied.	1	Tier 1; default IPCC emission factors used.	5	N/A	2	15

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Enteric fermentation													
	Agriculture	CH ₄	3,417.75	3%	2	32%	1 IPCC default emission factors or CSEFs from Thailand, Philippines, or Indonesia were applied.	3 Tier 1; default IPCC emission factors used.	5	N/A	2	13	
Rice cultivations	Agriculture	CH ₄	3,158.40	2%	2	30%	1 IPCC default emission factors or CS emission factors from Thailand, Philippines, or Indonesia were applied.	3 Tier 1; default IPCC emission factors used.	5	N/A	2	13	
Agricultural soils	Agriculture	N ₂ O	2,210.30	2%	2	21%	1 IPCC default emission factors or CSEFs from Thailand, Philippines, or Indonesia were applied.	3 Tier 1; default IPCC emission factors used.	5	N/A	2	13	

India

India submitted its NC2 to the UNFCCC in 2012 with a national GHG inventory for 2000. The emission factors used to estimate India's GHG emissions are a mix of default Tier 1 emission factors from IPCC and country-specific factors. Tier 2 and Tier 3 methodologies have been applied in some sectors where data are available. India performed a KCA (excluding LULUCF) for its inventory that included both level and trend analyses.⁴³ The level analysis identified 25 source categories with 15 from the energy sector, three from agriculture, four from industrial processes, and three from waste. The top fifteen key categories of the trend analysis make up the key sources of the level analysis. Although not included in the KCA, CO₂ removals from changes in forest and woody biomass and from forest and grassland conversion have been included in the emissions factor framework as these are two significant sources in India.

Energy sources that are key categories in both the level and trend analyses include: CO₂ emissions from stationary combustion for electricity generation (34.3 percent of total national emissions); CO₂ emissions from mobile source combustion for road transportation (5.6 percent); CO₂ emissions from stationary combustion for non-specific industries (3.9 percent); CO₂ emissions from stationary combustion for residential energy production (3.6 percent); total CO₂ emissions from iron and steel production (3.4 percent);⁴⁴ fuel combustion CO₂ emissions from cement production (2.6 percent); CH₄ emissions from stationary combustion for residential energy production (2.2 percent); CO₂ emissions from agriculture and fisheries energy production stationary combustion (1.9 percent); and CO₂ emissions from food and beverage production stationary combustion (1.6 percent). The other energy key categories identified in the level analysis are: stationary combustion CO₂ emissions from refineries; fugitive CH₄ emissions from oil and natural gas systems; stationary combustion CO₂ emissions from textile and leather production; fugitive CH₄ emissions from open cast coal mining; and CO₂ emissions from mobile source combustion for railways. These categories each account for approximately 1 percent or less of total national emissions.

Country-specific CO₂ emission factors for stationary combustion of coal have been derived for India on the basis of the net calorific values of different types of coal produced in the country, namely, coking, non-coking, and lignite. These country-specific factors were used in the NC2 energy sector emission estimates. CO₂ emissions from the energy sector (stationary and mobile combustion) were estimated using a mix of Tier 1 and Tier 2 methodologies while CH₄ and N₂O emissions were estimated using Tier 1 methodologies.

CH₄ emissions from enteric fermentation (13.9 percent of national emissions), CH₄ emissions from rice cultivation (4.9 percent), and N₂O emissions from agricultural soils (3.8 percent) were identified as key categories in both the level and trend analyses. Tier 3 methodologies were applied to estimate CH₄ emissions from enteric fermentation and rice cultivation. Livestock have been classified and sub-classified into indigenous and cross-bred types to provide country-specific emission factors for each

⁴³ A level analysis assesses which sources and sinks are most important to a national circumstance based on the emissions/removals of a given year. The study team determined that the key categories are those that account for 95 percent of total national emissions in the level analysis. A level analysis does not take into account the rate of growth of a source or sector, only the quantity of emissions at the time of the inventory.

⁴⁴ Iron and steel production emissions include both energy (fuel combustion) and IPPU (industrial process) emissions. The NC2 reports combined energy and IPPU emissions from iron and steel production under the energy sector and did not report any emissions from iron and steel production under IPPU sector.

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livestock type. The emission factors used for enteric fermentation emissions from cows, sheep, and buffaloes were derived from literature review, which are based on measurements and estimates based on the feed intake of the species. Emission factors for rice cultivation were developed based on actual water management practices in India. These factors are based on measurements of seasonal methane flux that have been carried out continuously since the 1990s. N₂O emissions from agricultural soils are estimated using Tier 2 methodologies and a mix of country-specific and default emission factors.

The level analysis identified four key categories from industrial processes: [IPPU] CO₂ emissions from cement production (2.9 percent of national emissions); CO₂ emissions from ammonia production (0.7 percent); CO₂ emissions from limestone and dolomite use (0.4 percent); and CF₄ emissions from metal (aluminum) production (0.4 percent). Carbon dioxide emissions from cement production is the only industrial process source identified in the trend analysis. Emissions from cement production are estimated using Tier 2 methodologies and some country-specific emission factors that are sourced from the NC1; all other industrial process sectors use Tier 1 methodologies and default emission factors.

The three waste sources identified in the level analysis are CH₄ emissions from industrial waste water management (1.5 percent of national emissions); CH₄ from domestic and commercial waste water management (1.5 percent); and CH₄ emissions from solid waste disposal on land (0.7 percent). Emissions from industrial waste water management, which is also a key source in the trend analysis, are estimated using Tier 1 and 2 methodologies. The CH₄ production potentials are based on industry sources and the amount of waste water generated in various industries was estimated using IPCC 2006 Guidelines.

According to the NC2's trend assessment, CO₂ emissions from stationary combustion for electricity generation has the greatest contribution to India's GHG trends accounting for 27.5 percent of total emissions. CH₄ emissions from enteric fermentation has a 15.6 percent contribution to national GHG emissions, followed by CO₂ emissions from energy (stationary combustion) for food and beverage production (9.2 percent), CO₂ emissions from mobile combustion for road transport (8.9 percent), and total CO₂ emissions from iron and steel production (7.5 percent). The energy sector is presently a major contributor to India's national emissions and will continue to be a significant source of emissions in the future.

India's NC2 provides a Tier 1 assessment of uncertainty that includes the uncertainty for emission factors, activity data, and estimates of combined uncertainty calculated using error propagation. The uncertainty associated with the emission factors for CO₂ emissions from energy (stationary and mobile combustion) sources is reported as 5 percent with the exception of the emission factors for road transport (mobile combustion), which are reported in the NC2 as 0 percent. The uncertainty associated with the emission factor for CH₄ emissions from residential energy (stationary combustion) is estimated at 150 percent, the highest for all the reported factors. Although efforts have been invested into improving CH₄ emission estimates from livestock enteric fermentation, the uncertainty associated with the emission factor for enteric fermentation is still quite high (50 percent). Other emission factors with high uncertainties include those for N₂O emissions from agricultural soils (100 percent) and CH₄ emissions from industrial wastewater management (125 percent).

Based on a weighted score that takes into account emission contribution, current status of emission factors, and uncertainty, the highest priority sector for emission factor improvement appears to be for CO₂ emissions from stationary combustion for electricity generation, given its large share of the total emissions and need for more accuracy in emission factors (see Table 4-5). Some emission factor refinement has already been conducted but additional focus may be needed due to the relative

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contribution from electricity generation.⁴⁵ CH₄ emissions from enteric fermentation and N₂O emissions from agricultural soils are other priority sectors for emission factor improvement. Secondary priorities include CO₂ emissions from mobile combustion for road transportation, CO₂ emissions from stationary combustion for residential energy, CH₄ emissions from industrial waste water management, CH₄ emissions from solid waste disposal on land, CO₂ emissions from limestone/dolomite production, and CF₄ emissions from metal (aluminum) production. The LULUCF sector was not included in the KCA but LULUCF sources are significant to India's national emissions and removals, particularly CO₂ removals from changes in forest and woody biomass (217,393.8 Gg) and CO₂ removals from forest and grassland conversion (18,788.0 Gg).

Nationally, even though a number of emissions factors have been developed to Tier 2 and Tier 3 standards, the improvement of factors that are currently Tier 1 default factors to Tier 2 and from Tier 2 to Tier 3, could certainly help bring additional accuracy to national inventory efforts. More broadly however, improved emission factors could help track mitigation efforts to meet the country's goal to reduce its emission intensity by 20 percent to 25 percent between 2005 and 2020 and to meet the GHG reduction objectives outlined in the National Action Plan on Climate Change developed in 2008.⁴⁶

Regionally, India is the most advanced of all LEAD countries in terms of both percentage of emissions captured by Tiers 2 and 3 (in total at approximately 79 percent), and not by Tier 1 default factors (only 21 percent).⁴⁷ India's efforts at developing and applying country-specific factors across a range of sectors (such as fuel combustion, enteric fermentation, rice cultivation, agricultural soils, and industrial process sources) present a significant potential for sharing the emission factors it has developed, including the methodological approaches and good practices employed, with other LEAD countries.

⁴⁵ Choudhary *et al.* (2004).

⁴⁶ The goal was announced in January 2010. See http://unfccc.int/files/meetings/cop_15/copenhagen_accord/application/pdf/indiacphaccord_app2.pdf. Ministry of Environment (2010, June). "India: Taking on Climate Change—Post Copenhagen Domestic Actions." India. See <http://moef.nic.in/downloads/public-information/India%20Taking%20on%20Climate%20Change.pdf>

⁴⁷ INCCA (2010).

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Table 4-5: Emission Factor Framework for India

Source Category (level)	Sector	Gas	Emissions Estimate (Gg of CO ₂ e-eq.)	% Share of Total National Emissions		% Share of Sector Emissions		Ease of Moving to a Higher Tier Emission Factor		Tier and Emission Factor		Uncertainty with Emission Factor		Total Weight
				Value: x%	Weight Factor	Value: x%	Weight Factor		Weight Factor	Description	Weight Factor	Value	Weight Factor	
Electricity generation (stationary combustion) *	Energy	CO ₂	522,495.4	34.3%	12	51%	2	Country-specific CO ₂ emission factors derived for different types of coal produced in the country. (Choudhary et. al., 2004)	1	Tier 2; CSEFs used.	1	5%	1	17
Enteric fermentation *	Agriculture	CH ₄	211,429.4	13.9%	6	59%	2	CSEFs based on livestock population classified into indigenous and cross-bred types in India. ⁴⁸	3	Tier 3; CSEFs used.	1	50%	3	15
Road transport (mobile combustion) *	Energy	CO ₂	85,515.8	5.6%	4	8%	1	Not described in NC2.	2	Tier 1; default IPCC emission factors used.	5	N/A	1	13
Rice cultivation *	Agriculture	CH ₄	74,360.6	4.9%	2	21%	1	Based on water management practice. The emission factors are based on long-term field measurement. ⁴⁹	3	Tier 3; CSEFs used.	1	8%	1	8
Non-specific industries (stationary combustion) ⁵⁰ *	Energy	CO ₂	58,717.2	3.9%	2	6%	1	Not described in NC2.	1	Tier 1.	5	5%	1	10

⁴⁸ NC2, pgs. 60 and 61.

⁴⁹ NC2, pg. 63.

⁵⁰ Non-specific industries considered include rubber, plastic, watches, clocks, transport equipment, and furniture. Pg. 48, NC2.

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Agricultural soils*	Agriculture	N ₂ O	57,810.5	3.8%	2	16%	1	Not described in NC2	3	Tier 2, CSEF and default emission factors used.	5	100%	3	14
Residential (stationary combustion) *	Energy	CO ₂	55,182.0	3.6%	2	5%	1	Not described in NC2	1	Tier 1.	5	N/A	2	11
Iron and steel*	Energy and IPPU	CO ₂	52,366.0	3.4%	2	5%	1	Based on a number of studies. ⁵¹	3	Tier 1 factors for IPPU CO ₂ emissions, Tier 2 emission factor for domestic coal / coke carbon content	1	N/A	2	9
Cement (process emissions)*	IPPU	CO ₂	44,056.0	2.9%	2	50%	2	Same as Initial National Communication.	2	Tier 2	3	N/A	2	11
Cement (stationary combustion) *	Energy	CO ₂	39,696.0	2.6%	2	4%	1	Not described in NC2.	1	Tier 1 / Tier 2	5	5%	1	10
Chemicals (stationary combustion) *	Energy	CO ₂	34,482.4	2.3%	2	3%	1	Not described in NC2.	1	Tier 1.	5	N/A	2	11
Residential (stationary combustion) *	Energy	CH ₄	33,894.0	2.2%	2	3%	1	Not described in NC2.	1	Tier 1.	5	150%	3	12
Agricultural/ fisheries (stationary combustion) *	Energy	CO ₂	28,347.0	1.9%	2	3%	1	Not described in NC2.	1	Tier 1.	5	5%	1	10
Food and beverages (stationary combustion) *	Energy	CO ₂	24,577.9	1.6%	2	2%	1	Not described in NC2.	1	Tier 1.	5	5%	1	10

⁵¹ NC2, pg. 42.

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Industrial waste water treatment*	Waste	CH ₄	23,163.0	1.5%	2	44%	2	Assessment of CH ₄ production based on industrial sectors that have degradable organic matter in their waste water. Data on industrial waste water obtained through literature research and industrial visits. ⁵²	2	Tier 1/Tier 2; emission factors derived from IPCC.	3	125%	3	12
Refinery (stationary combustion)	Energy	CO ₂	18,695.9	1.2%	2	2%	1	Not described in NC2.	1	Tier 1.	5	N/A	2	11
Domestic and commercial waste water treatment	Waste	CH ₄	15,036.0	1.0%	2	N/A	N/A	B ₀ was taken as 0.6 and MCFs were taken from IPCC 2006.	2	Tier 1; emission factors derived from IPCC.	3	N/A	2	9
Fugitive emissions from natural gas	Energy	CH ₄	14,668.3	1.0%	2	1%	1	IPCC default emission factors used.	3	Tier 1; default IPCC emission factors used.	5	N/A	2	13
Ammonia production	IPPU	CO ₂	11,067.3	0.7%	2	N/A	N/A	Emission factors based on expert judgment by Fertilizer Association of India and studies from USEPA.	2	Tier 1/Tier 2.	5	N/A	2	11
Solid waste disposal on land	Waste	CH ₄	10,252.0	0.7%	2	20%	1	Not described in NC2.	2	Tier 2; CSEF and default.	5	N/A	2	12
Textile/leather (stationary combustion)	Energy	CO ₂	7,669.1	0.5%	2	1%	1	Not described in NC2.	1	Tier 1.	5	N/A	2	11
Open cast coal mining	Energy	CH ₄	12,298.74	0.5%	2	1%	1	Not described in NC2.	1	Tier 2; CSEFs used	5	N/A	2	11
Limestone/dolomite use	IPPU	CO ₂	5,961.7	0.4%	2	7%	1	Not described in NC2.	2	Tier 1.	5	N/A	2	12

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Aluminum production	IPPU	CF ₄	5,655.0	0.4%	2	6%	1	Not described in NC2.	2	Tier 1.	5	N/A	2	12
Railways (mobile combustion)	Energy	CO ₂	5,426.3	0.4%	2	1%	1	IPCC 2006 default emission factors used for coal, diesel, petrol, light Diesel Oil, Fuel Oil, kerosene, and fuel wood.	2	Tier 1, default IPCC emission factors used	5	N/A	2	12

* Key level and trend sources
N/A: not available

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Indonesia

Indonesia initially submitted its NC2 to the UNFCCC in January 2011 and resubmitted an updated NC2 in January 2012. This NC provides emissions estimates for the period 2000 to 2005 with a focus on the estimates for the year 2000. The NC2 includes a Tier 1 KCA with and without LULUCF that identified 20 and five key categories, respectively. There appear to be inconsistencies in the sorting of categories in the KCA, based on ICF's review of the NC2 and an independent KCA analysis that ICF undertook.

Based on an independent KCA, 16 key sources were identified. Of these 16 categories, five are from LULUCF (CO₂ emissions from forests converted to grassland, CO₂ emissions from forest soils, CO₂ removals from changes in forest and woody biomass, CO₂ emissions from peat fires, and CO₂ removals from abandoned managed lands), two are from waste (CH₄ emissions from industrial waste water and CH₄ emissions from unmanaged waste disposal and dumpsites), five are from energy (CO₂ emissions from stationary combustion in energy production, CO₂ emissions from stationary combustion in manufacturing and construction, CO₂ emissions from mobile combustion, CO₂ emissions from stationary combustion in residential energy, and CH₄ fugitive emissions from oil and natural gas systems), two are from agriculture (CH₄ emissions from rice cultivation and direct N₂O emissions from managed soils), one was from industrial processes (CO₂ emissions from cement production), and one was from "Other" (CO₂ emissions from biomass).

Approximately 64 percent of total emissions and removals are from LULUCF sources, particularly: CO₂ emissions from forest land converted to grassland (34 percent of national emissions); CO₂ emissions from soils (10 percent); CO₂ removals from changes in woody and forest biomass (10 percent); CO₂ emissions from forest burning (8 percent); and CO₂ emissions/removals from abandoned croplands and pastures (3.8 percent). For LULUCF, it appears that a mix of default and country-specific factors are used for estimating emissions. Indonesia estimates that the emission factor uncertainty for forest and grassland conversion and soil emissions is 75 percent. The uncertainty associated with emission factors for changes in woody and forest biomass, abandoned managed land, and peat burning is estimated to be 50 percent.

Emissions for LULUCF are now calculated at the provincial level through the Local Action Plan for GHG Emission Reductions ("RAD-GRKs").⁵³ A major challenge the country faces is the harmonization and aggregation of provincial data into a national estimation. Peatlands is one of the largest sources of emissions in Indonesia and has an associated uncertainty that, by some estimates exceeds that stated in the NC2.⁵⁴ Uncertainty is identified in the NC2 as 25 percent for the activity data and 50 percent for the emission/removal factors for peatlands.⁵⁵ A key area of uncertainty for peatlands is related to drained peatland areas where emission estimates are difficult to reliably calculate. The Indonesian Climate Change Center (ICCC) is working on improving emission factors for peatlands, particularly related to drained peat and swamp areas, oil palm plantations in peatlands, and the use of fertilizers in peatlands. The ICCC is also focusing on soil carbon and related emissions as this is an important cross-cutting sector. The ICCC identifies soil carbon as a priority for further emission factor research.⁵⁶

⁵³ Expert consultations, USAID Country Missions, March 19, 2013.

⁵⁴ Expert consultations, ICCC, March 19, 2013.

⁵⁵ Table 2.17, NC2.

⁵⁶ Expert consultations, ICCC, March 19, 2013.

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Methane emissions from industrial wastewater treatment and disposal and unmanaged waste disposal and dumpsites are the two key sources from the waste sector. These two sectors combined contributed 6.6 percent of national GHG emissions in 2000. The emissions appear to be estimated in the NC2 using Tier 1 methodologies and default emission factors and the NC2 has noted that the uncertainty of waste activity data and waste emission factors is 50 percent.⁵⁷

The five key sources from the energy sector include: CO₂ emissions from stationary combustion for energy production (3.9 percent of national emissions); CO₂ emissions from stationary combustion in manufacturing and construction (2.9 percent); CO₂ emissions from mobile combustion (2.6 percent); CO₂ emissions from stationary combustion for residential energy (1.1 percent); and CH₄ emissions from oil and natural gas systems fugitive emissions (0.8 percent). Total CO_{2e} emissions from the energy sector grew through the period of 2000 to 2005⁵⁸ and are expected to continue to grow in the future. According to the NC2, the annual GHG emissions growth rate from fuel consumption in Indonesia was higher than the Indonesian economic growth rate. The uncertainty for emission factors from the energy sector is estimated to be 5 percent.

Since the NC2 was completed, electricity grid emission factors at the provincial level have been developed. These emission factors and the activity data for electricity generation will be improved by State Ministry of National Development Planning (BAPPENAS) with the support of JICA and GIZ. This information will be aggregated to the national level in the spring of 2013. Mobile combustion is an energy source that is being considered for emission factor improvement. Varying fuel economies, shifts in the mode of transport, and the difficulty of data collection are challenges to developing representative emission factors in this sector.

CH₄ emissions from rice cultivations and N₂O emissions from agricultural soils contributed 2.3 percent of national emissions in 2000. A Tier 2 approach utilizing emission factors based on the cultivation regimes is used to estimate emissions from rice cultivations. A Tier 1 approach with default emission factors is used to estimate N₂O emissions from soils. The NC2 provides an overall uncertainty of 30 percent for all agricultural sector emission factors.

IPPU CO₂ emissions from cement production accounts for 1.6 percent of total emissions and CO₂ emissions from combustion of biomass) accounts for 8.2 percent of national emissions. There is limited information available about the estimation methods for these sectors but it appears that a Tier 1 approach is used for both these source categories. The uncertainty associated with the emission factors for industry is estimated to be 10 percent.

Based on the Emission Factor Framework in Table 4-6, the top three priority sectors for emission factor improvement are: CO₂ emissions from forests converted to grassland; CO₂ removals from forest and woody biostock; and CO₂ emissions from soils. These three sectors account for 54 percent of total emissions, thus refining these emission factors is important for reducing the uncertainty of the national inventory. CH₄ emissions from industrial wastewater and CO₂ emissions from biomass combustion are secondary priorities for emission factor improvement.

The Government of Indonesia (GOI) announced an emissions reduction target of 26 percent below business as usual (BAU) levels by 2020 at COP15. The GOI aims to reduce emissions by an additional 15

⁵⁷ Table 2.17 of the NC2

⁵⁸ Table 1b of the NC2. Summary of GHG emissions from 2000-2005 from all sectors (in Gg CO₂-eq.)

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percent with support from developed countries. In 2011, the GOI finalized its National Action Plan for Greenhouse Gas Emission Reductions (Rencana Aksi Nasional-Gas Rumah Kaca or “RAN-GRK”) aiming to meet that goal along with provincial actions plans (RAD-GRKs), most of which will be completed this year.⁵⁹ Indonesia also is developing the Nusantara Carbon Scheme, a voluntary project-based carbon market program. Efforts to develop CSEFs will help to bring accuracy in meeting the goals of these programs, particularly in relation to tracking mitigation efforts.

Efforts to improve emission factors should be coordinated with other programs underway such as Indonesia’s National GHG Inventory System (SIGN) program and international ones such as from JICA, GIZ, and Australia’s Indonesian National Carbon Accounting System (INCAS) program focused on LULUCF. Given the importance of forestry both in terms of REDD potential and dominant share of both emissions and sinks in the country, any efforts at improving LULUCF emission factors need to be well-coordinated with other programs also focused in this area. Finally, given the significance of Indonesia’s emissions, particularly in the LULUCF sector, any efforts at improving emission factors towards Tier 2 and 3 levels, would benefit not only the country but potentially the rest of the region with regard to how such CSEFs are developed and the methodological approaches employed.

⁵⁹ Expert consultations, USAID Country Missions, March 19, 2013.

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Table 4-6: Emission Factor Framework for Indonesia

Source Category (level)	Sector	Gas	Emissions Estimate (gg of CO ₂ -eq.)	% Share of Total National Emissions		% Share of Sector Emissions		Ease of Moving to a Higher Tier Emission Factor		Tier and Emission Factor		Uncertainty with Emission Factor		Total Weight
				Value: x%	Weight Factor	Value: x%	Weight Factor	Description of EF	Weight Factor	Description	Weight Factor	Value	Weight Factor	
Forest and grassland conversion (emissions)		CO ₂	729,655.23	34%	12	52%	2	Mix of different forest species and adjustment / scaling factors.	3	Tier1/2.	3	75%	3	23
Forest soils	LULUCF	CO ₂	216,313.00	10%	6	15%	1	Not described in NC2.	3	Tier 1/2	5	75%	3	18
Changes in forest and other woody biomass (removals)	LULUCF	CO ₂	(215,154.00)	10%	6	-15%	1	Mix of different forest species and adjustment / scaling factors.	3	Tier 1/2	5	50%	3	18
Biomass	Other	CO ₂	176,765.69	8.2%	4	100%	3	IPCC default emission and conversion factors used.	3	Tier I	5	N/A	2	17
Peat fires	LULUCF	CO ₂	172,000.00	8.0%	4	12%	1	IPCC default emission and conversion factors used.	3	Unknown. ⁶⁰	3	50%	3	14
Industrial waste water treatment	Waste	CH ₄	123,997.23	5.8%	4	79%	3	IPCC default emission and conversion factors used.	2	Tier 1.	5	50%	3	17

⁶⁰ Emission from peat fire was taken from van der Werf *et al* (2008). Table 1b of Indonesia Inventory.

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Energy production (electricity, heat, oil, & gas refining) (stationary combustion)	Energy	CO ₂	84,011.42	3.9%	2	33%	2	IPCC default emission and conversion factors used.	1	Tier 1.	5	5%	1	11
Abandonment of managed lands (removals)	LULUCF	CO ₂	(81,639.89)	3.8%	2	-6%	1	Not described in NC2.	3	Tier 1/2	3	50%	3	12
Manufacturing industries and construction (stationary combustion)	Energy	CO ₂	63,032.00	2.9%	2	25%	1	IPCC default emission and conversion factors used.	1	Tier 1	5	5%	1	10
Mobile combustion	Energy	CO ₂	55,689.23	2.6%	2	22%	1	IPCC default emission and conversion factors used.	2	Tier 1	5	5%	1	11
								Mix of different rice/biomass cultivation regimes.						
Rice cultivations	Agriculture	CH ₄	34,860.63	1.6%	2	46%	2	IPCC default emission and conversion factors used.	3	Tier 2	1	30%	2	10
Cement ⁶¹	IPPU	CO ₂	25,006.00	1.2%	2	59%	2		2	Tier 1	5	30%	2	13
Residential (stationary Combustion)	Energy	CO ₂	23,878.82	1.1%	2	9%	1	IPCC default emission and conversion factors used.	1	Tier 1	5	5%	1	10

⁶¹ Indonesia did not separately report energy emissions for cement production.

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Fugitive emissions from oil and natural gas	Energy	CH ₄	20,247.57	0.9%	2	8%	1	IPCC default emission and conversion factors used.	3	Tier 1	5	5%	1	12
Unmanaged waste disposal and dumpsites	Waste	CH ₄	18,113.55	0.8%	2	12%	1	IPCC default emission and conversion factors used.	2	Tier 1	5	50%	3	13
Managed soils (direct N ₂ O emissions)	Agriculture	N ₂ O	15,534.10	0.7%	2	21%	1	IPCC default emission and conversion factors used.	3	Tier 1	3	30%	2	11

Laos

Laos submitted its NC1 in October 2000 that included a GHG inventory for 1990. This first GHG inventory estimated emissions from energy, LULUCF, agriculture, and waste sectors using IPCC methodologies and emission factors. There are four key categories in Laos, of which three are from LULUCF (CO₂ emissions from forestland remaining forestland, CO₂ removals from forestland remaining forestland, and CO₂ emissions from aboveground decay) and one is from agriculture (CH₄ from rice cultivations). Changes in woody and forest biomass accounted for the removal of 121,614 Gg CO₂ in 1990. Carbon dioxide emissions from aboveground forest decay and forest conversion, the second and third key categories, account for 9,247.84 and 6,752.7 Gg CO₂. Emissions from rice cultivation, the fourth key category, accounts for 3,338 Gg CO₂-eq., or approximately 2 percent of national emissions.

The NC1 states that there are no country-specific emission factors for Laos and there is a lack of capacity to develop CSEFs. Given its significance to Laos' emission profile, LULUCF, particularly CO₂ removals by forests, is a priority for any future emission factor development. A summary of the key source categories and the weighted scores is presented in Table 4-7. Some activity data, such as crop areas, are reliable but there are gaps in activity data for the majority of the sectors.

At the international level, Laos has signed the Copenhagen Accord and identified a series of priority actions on NAMAs toward a low-carbon economy. Climate change is being mainstreamed into Laos's national development planning process where both unilateral and internationally supported measures are under way.⁶² Laos continues to formulate policies and institutional frameworks to reduce vulnerability to natural disasters, increase the use of renewable energy, mitigate transportation sector emissions, achieve 70 percent forestry cover by 2020, and reduce emissions from deforestation and forest degradation. The government of Laos envisions preparation of NAMAs, action plans for the National Strategy on Climate Change (NSCC), capacity building, and generation and mobilization of greater resources.⁶³ Any efforts at improving emission factors would likely contribute to bringing accuracy in tracking mitigation efforts of the above-mentioned initiatives, particularly the NSCC which has seven mitigation objectives. Additionally, given that USAID/RDMA's LEAF program is conducting forest-level activities in Laos, any efforts at improving forest-related emission factors should be coordinated with LEAF in order to maximize synergies.

⁶² Laos has developed a NAMA project to develop an urban transport master plan for Vientiane for funding consideration by the Japanese Ministry of Environment Ecofys Report on NAMAs. See http://www.ecofys.com/files/files/namas_annualstatusreport_2011.pdf.

⁶³ Sengchandala, Syamphone (2010).

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Table 4-7: Emission Factor Framework for Laos

Source Category (Level)	Sector	Gas	Emissions Estimate (Gg of CO ₂ e-eq.)	% Share of Total National Emissions		% Share of Sector Emissions		Ease of Moving to a Higher Tier Emission Factor		Tier and Emission Factor		Uncertainty with Emission Factor		Total Weight
				Value: x%	Weight Factor	Value: x%	Weight Factor	Description of Emission Factor	Weight Factor	Description	Weight Factor	Value	Weight Factor	
Forest land remaining forest land (Removals)	LULUCF	CO ₂	(121,614)	83.4%	12	-88%	3	Emission factors and growth rates are default IPCC values.	3	Tier 1: default IPCC emission factors used.	5	Same as IPCC.	3	26
Aboveground decay (emissions)	LULUCF	CO ₂	9,247.6	6.3%	2	7%	1	Emission factors and growth rates are default IPCC values.	3	Tier 1: default IPCC emission factors used.	5	Same as IPCC.	3	14
Forest land remaining forest land (emissions)	LULUCF	CO ₂	6,752.7	4.6%	2	5%	1	Emission factors and growth rates are default IPCC values.	3	Tier 1: default IPCC emission factors used.	5	Same as IPCC.	3	14
Rice cultivations	Agriculture	CH ₄	3,338.4	2.3%	2	59%	2	IPCC default values were used for both continuously flooded and intermittently flooded rice.	3	Tier 1: default IPCC emission factors used.	5	Same as IPCC.	3	15

Malaysia

Malaysia submitted its NC2 to the UNFCCC in 2011. The NC2, which reported emissions for 2000, included all five IPCC sectors and as well as more disaggregated sources. Local emission factors were applied when possible and IPCC default factors were used in other cases. The NC2 included a KCA that included LULUCF emissions and an analysis that excluded LULUCF.

The KCA including LULUCF identified 11 key categories. The top three sources were all related to CO₂ emissions from the energy sector (including stationary combustion for energy industries, mobile combustion for transport, and stationary combustion for manufacturing industries and construction) and accounted for 53.9 percent of total national emissions. CH₄ emissions from landfills, CO₂ emissions from forest and grassland conversion, and fugitive CH₄ emissions from oil and natural gas systems each account for approximately 10 a percent of national emissions. The remaining key categories (CO₂ emissions from mineral products (cement), CO₂ emissions from soils, CO₂ emissions from metal production (iron and steel), CO₂ emissions from stationary combustion for commercial energy, and CH₄ emissions from rice production) account for approximately 10 percent of national emissions.

When LULUCF is excluded from the KCA, there are 10 sources that account for 95 percent of total national emissions. The same energy, waste, industrial processes, and agriculture key sources have been identified as with the KCA that includes LULUCF and CO₂ emissions from stationary combustion for residential energy is added as the tenth key source. When LULUCF is excluded from the KCA, the top three energy industries (stationary combustion for energy industries, mobile combustion for transport, and stationary combustion for manufacturing and construction) account for 61.9 percent of total national emissions. CH₄ emissions from landfills and fugitive CH₄ emissions from oil and natural gas systems account for 12.7 and 11.4 percent of national emissions, respectively.

In either scenario (with or without LULUCF), energy is the dominant sector that accounts for the majority of Malaysia's emissions. Default IPCC emission factors were used to estimate energy sector emissions in NC1, NC2, and the forthcoming NC3. The Malaysia Global Training Center (MGTC) is the agency responsible for calculating energy and industrial process sector emissions and has stated that 2011 and 2012 emissions data are internally available and pending release to the public.⁶⁴ Some oil and natural gas stakeholders have suggested that different emission factors from MGTC should be applied for oil and gas based on their own GHG accounting method.

Table 4-8 provides a summary of the key source categories for Malaysia. Based on a weighted score, CO₂ emissions from stationary combustion for energy industries, CO₂ emissions from mobile combustion, CO₂ emissions from forest and grassland conversion, CO₂ emissions from stationary combustion for manufacturing and construction, and CH₄ emissions from landfills are priority sources for future emission factor development based on their relative contribution to national emissions and the ease of emission factor improvement. Default emissions factors are used to estimate all emissions in the NC2 for Malaysia and therefore, if resources are available, all other key source emission factors should also be improved. The MGTC has stated that there are no specific plans to develop country-specific emission factors for Malaysia at this point.⁶⁵ Any efforts to develop local emission factors would include the Economic Planning Unit, MGTC, Energy Commission, Sustainable Energy Development Authority,

⁶⁴ Expert consultations with MGTC, March 12, 2013.

⁶⁵ Expert consultations with MGTC, March 12, 2013.

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Standards and Industry Research Institute of Malaysia, PETRONAS, Malaysia DOE (Department of Environment), Malaysia Ministry of Natural Resource and Environment (NRE), Forest Research Institute of Malaysia, and Malaysia Agricultural Research and Development Institute.

Improvements in emission factors could certainly bring accuracy not only to national inventory efforts but broader climate change mitigation policies in the country, particularly in relation to more closely determining if abatement objectives have been met in the future. At COP15 in Copenhagen, the Malaysian Prime Minister Najib Razak announced an “indicator of a voluntary reduction” in emissions intensity of up to 40 percent relative to GDP from 2005 through 2020, subject to Malaysia receiving adequate finance and technology transfer from industrialized nations. The National Policy on Climate Change was released in 2009 and was a product of a Policy Study on Climate Change funded under the Ninth Malaysia Plan. The Tenth Malaysia Plan expresses priority for climate change adaptation and mitigation, with five key issues on the latter (renewable energy, energy efficiency, solid waste management, forest conservation, and other emissions reductions options).

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Table 4-8: Emission Factor Framework for Malaysia

Source Category (level)	Sector	Gas	Emissions Estimate (Gg of CO ₂ e-eq.)	% Share of Total National Emissions		% Share of Sector Emissions		Ease of Moving to a Higher Tier Emission Factor	Tier and Emission Factor		Uncertainty with Emission Factor	Total Weight t		
				Value: x%	Weight Factor	Value: x%	Weight Factor		Description	Weight Factor			Value	Weight Factor
Energy industries (stationary combustion)	Energy	CO ₂	58,486	26.2%	12	39.8%	2	IPCC defaults.	1	Tier 1; default IPCC emission factors used.	5	Same as IPCC.	3	23
Mobile combustion	Energy	CO ₂	35,587	16.0%	8	24.2%	1	IPCC defaults.	2	Tier 1; default IPCC emission factors used.	5	Same as IPCC.	3	19
Manufacturing industries and construction (stationary combustion)	Energy	CO ₂	26,104	11.7%	6	17.8%	1	IPCC defaults.	1	Tier 1; default IPCC emission factors used.	5	Same as IPCC.	3	16
Solid waste (landfill)	Waste	CH ₄	24,541	11.0%	6	82.9%	3	IPCC defaults.	2	Tier 1; default IPCC emission factors used.	5	Same as IPCC.	3	19
Forest and grassland conversion (emissions)	LU/LUCF	CO ₂	24,111	10.8%	6	-9.7%	1	IPCC defaults.	3	Tier 1; default IPCC emission factors used.	5	Same as IPCC.	3	18
Fugitive emissions from oil and natural gas	Energy	CH ₄	21,987	9.9%	4	15.0%	1	IPCC defaults.	3	Tier 1; default IPCC emission factors used.	5	Same as IPCC.	3	16
Mineral products (cement production, lime production, and limestone and dolomite use)	IPPU	CO ₂	9,776	4.4%	2	69.2%	3	IPCC defaults.	2	Tier 1; default IPCC emission factors used.	5	Same as IPCC.	3	15
Forest soils (emissions and removals)	LU/LUCF	CO ₂	4,638	2.1%	2	-1.9%	1	IPCC defaults.	3	Tier 1; default IPCC emission factors used.	5	Same as IPCC.	3	14
Metal production (iron and steel)	IPPU	CO ₂	2,797	1.3%	2	19.8%	1	IPCC defaults.	2	Tier 1; default IPCC emission factors used.	5	Same as IPCC.	3	13
Commercial (stationary combustion)	Energy	CO ₂	2,122	1.0%	2	1.4%	1	IPCC defaults.	1	Tier 1; default IPCC emission factors used.	5	Same as IPCC.	3	12
Rice cultivations	Agriculture	CH ₄	1,861	0.8%	2	31.5%	1	IPCC defaults.	3	Tier 1; default IPCC emission factors used.	5	Same as IPCC.	3	14

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Nepal

Nepal developed a national GHG inventory for the year 1994 as part of its NC1 to the UNFCCC, which was submitted in 2004. This was the second national inventory conducted for Nepal; the Department of Hydrology and Meteorology prepared an inventory for the base year 1990 in 1997 with financial assistance from USAID.

The 1994 GHG inventory was prepared using IPCC Guidelines and primarily uses default emission factors. There are eight key sources of emissions in Nepal, with two from LULUCF (CO₂ emissions from forestland converted to cropland and CO₂ removals from changes in forest and woody biomass), five from agriculture (CH₄ emissions from enteric fermentation, N₂O emissions from managed soils, CH₄ emissions from rice cultivations, CO₂ emissions from managed soils, and CH₄ emissions from manure management), and one from the energy sector (CH₄ emissions from biomass combustion). CO₂ emissions from forest land converted to cropland and CO₂ removals from changes in forest and woody biomass account for 27 and 21.5 percent of national emissions and removals, respectively. CH₄ emissions from enteric fermentation account for 16.1 percent of national emissions. N₂O emissions from pasture, range, and paddock, agricultural fields, and indirect atmospheric decomposition of ammonia and nitrogen oxides (NO_x), collectively account for 12.2 percent of Nepal's emissions. Methane emissions from rice cultivation, which accounts for 9.4 percent of total emissions, are estimated using a combination of emission factors, scaling factors, and correction factors. Some of these factors may be country-specific but it is unclear from the NC1 how these were derived. The only energy sector key category is CH₄ emissions from the combustion of biomass (agricultural wastes, dung, and fuel wood), which accounts for 2.2 percent of total emissions. CH₄ emissions from manure management and N₂O emissions from managed soils are the other key categories in Nepal.

Table 4-9 provides a summary of the key source categories in Nepal and the weighted scores assigned to each sector. Given that a Tier 1 approach appears to have been applied to all sectors, prioritizing emission factor improvement is based on the relative contribution of each source to national emissions. CO₂ emissions from forest land converted to cropland is the highest priority for emission factor refinement given its relative contribution to Nepal's total emissions, followed by CO₂ removals from changes in woody and forest biomass, and CH₄ emissions from enteric fermentation. N₂O and CO₂ emissions from managed soils and CH₄ emissions from rice cultivations are secondary priorities for emission factor development. Although not key categories in 1994, CO₂ emissions from stationary and mobile combustion are two very fast growing sectors in Nepal and should also be considered for future emission factor improvement. It is not clear whether there are any studies or efforts to improve emission factors being conducted in Nepal at this time.

The Government of Nepal approved the Nepal Climate Change Policy shortly after COP16 in Cancun, Mexico. The policy's seven objectives include reducing GHG emissions from various sectors. In addition, city-level GHG inventories may have been considered or developed as part of a 2009 collaborative initiative between the Municipality Association of Nepal and Local Governments for Sustainability (ICLEI)–South Asia for Kathmandu and Pokhara.⁶⁶ Efforts to improve emission factors to bring them from

⁶⁶ Additional information is available from ICLEI - South Asia as part of the Roadmap of South Asian Cities and Local Governments for a post-2012 Global Climate Agreement and Actions project supported by the British High Commission. See <http://www.iclei.org/index.php?id=10459>. The "Kathmandu Call" is available at: http://www.iclei.org/fileadmin/template/project_templates/climate-roadmap/files/National-local_Dialogue/Indian_Workshop_and_Calls/Kathmandu_Call.pdf.

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Tier 1 default values to Tier 2/ Tier 3 methodologies would contribute to increased accuracy for GHG reduction activities in these national and sub-national initiatives.

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Table 4-9: Emission Factor Framework for Nepal

Source Category (level)	Sector	Gas	Emissions Estimate (Gg of CO ₂ -eq.)	% Share of Total National Emissions		% Share of Sector Emissions		Ease of Moving to a Higher Tier Emission Factor		Tier and Emission Factor		Uncertainty with Emission Factor		Total Weight
				Value : %	Weight Factor	Value : %	Weight Factor	Description of EF	Weight	Description	Weight Factor	Value	Weight Factor	
Forest and cropland conversion (emissions)	LULUCF	CO ₂	18,547	27%	12	49%	2	IPCC default values used.	3	Tier 1; default IPCC emission factors used.	5	Same as IPCC.	3	25
Changes in forest and other woody biomass (removals)	LULUCF	CO ₂	(14,738)	21%	10	-39%	2	IPCC default values used.	3	Tier 1; default IPCC emission factors used.	5	Same as IPCC.	3	23
Enteric fermentation	Agriculture	CH ₄	11,067	16%	8	41%	2	IPCC default values used.	3	Tier 1; default IPCC emission factors used.	5	Same as IPCC.	3	21
Agricultural soils	Agriculture	N ₂ O	8,370	12%	6	31%	2	Pasture, range, and paddock accounted for 41%, of direct N ₂ O from agricultural fields (excluding histosols) for 31%, and indirect N ₂ O for 28%. ⁶⁷	3	Tier 1; default IPCC emission factors used.	5	Same as IPCC.	3	19
Rice cultivations	Agriculture	CH ₄	6,426	9%	4	24%	2	Combination of harvested area, scaling factor for CH ₄ emissions (between 0.4 - 1), organic amendment emissions factor (usually 2), and other correction factor (usually 20). ⁶⁸	3	Unclear; possibly Tier 2.	3	Unknown.	2	14
Agricultural	Agriculture							IPCC default values		Tier 1; default IPCC emission factors				

⁶⁷ Pg. 26, NC1.

⁶⁸ Table 3.4, NC1.

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soils	e							used.		used.				
Biomass (stationary combustion)	Energy	CH ₄	1,491	2%	2	46%	2	IPCC default values used.	1	Tier 1; default IPCC emission factors used.	5	Same as IPCC.	3	13
Manure management	Agriculture	CH ₄	714	1%	2	3%	1	IPCC default values used.	3	Tier 1; default IPCC emission factors used.	5	Same as IPCC.	3	14

Philippines

The Philippines submitted its NC1 in May 2000 with a GHG inventory for the year 1994. The inventory was conducted using a mix of Tier 1 and Tier 2 methodologies; with local emission factors applied where possible. There are 14 key categories identified for the Philippines: two from LULUCF, five from energy, four from agriculture, two from industrial processes, and one from waste.

CO₂ removals from changes in forest and woody biomass accounted for 23.8 percent of national emissions, while CO₂ emissions/removals from forest and land use change accounted for 22.9 percent of the total emissions. Emissions from LULUCF appear to be estimated using a mix of IPCC default values and local values from the Forestry Development Center of the University of the Philippines at Los Baños. Biomass growth rates, densities, and carbon contents were primarily taken from a 1999 study entitled *Forest Land Use Change in the Philippines and Climate Change Mitigation*.⁶⁹

There are a number of uncertainties associated with the emission estimates for LULUCF: the impact of soil carbon and biomass growth in abandoned lands is unknown; the uncertainties associated with local biomass densities and growth rates are not well understood; and there are uncertainties in the derivation of forest/non-forest land areas and their temporal changes.⁷⁰ Elementary exponential extrapolation was used wherever gaps existed or wherever the administrative classification of forest biomass types (such as old growth dipterocarp forests) did not reflect the reality. The various fates of biomass resulting from the conversion of land were likewise inferred from studies such as the World Bank Energy Sector Management Assistance Program (ESMAP).⁷¹

The five key sources from the energy sector include: CO₂ emissions from biomass combustion (17 percent of national emissions); CO₂ emissions from mobile combustion (5.5 percent); CO₂ emissions from solid fuel combustion (5.4 percent); CO₂ emissions from stationary combustion in manufacturing and construction (3.1 percent); and CO₂ emissions from stationary combustion in commercial and industry energy (1.2 percent). These emissions were estimated using IPCC default emission factors for the NC2. For the purposes of carbon content and heating value, all coal consumption was assumed to be “sub-bituminous coal,” all gasoline types were classified as “gasoline,” kerosene was assumed to be “other kerosene,” and diesel fuel was assumed to be “gas/diesel oil” according to the “IPCC Equivalent of Local Fuel Types.”

In March 2011, the Ministry of Land, Infrastructure, Transport, and Tourism (MLITT) released an assessment on vehicle emission factors for the Philippines.⁷² Vehicle emission factors are calculated using an emission factor unit, Philippines exhaust gas regulation classification, vehicle number, and the Philippines exhaust gas regulatory classification. The emission factor unit is calculated from exhaust gas obtained in chassis dynamometer (C/D) tests or by measurement in a running survey. The University of the Philippines is the only institution in the country with C/D testing capabilities. At the time of the report, the exhaust gas analyzer to carry out above-mentioned tests had not been installed and measurements could not be made, thus the emission factor unit and emission factors could not be determined. MLITT stated that the cost of the hardware necessary for making measurements is a barrier

⁶⁹ Lasco, R.D. and F.B. Pulhin (1999).

⁷⁰ Pg. 26, NC1.

⁷¹ Pg. 23, NC1.

⁷² MLITT (2011).

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to determining emission factors from vehicles.

The key categories from agriculture include: CH₄ emissions from rice cultivations (4.7 percent of national emissions); direct N₂O emissions from managed soils (3 percent); CH₄ emissions from enteric fermentation (2.4 percent); and N₂O emissions from manure management (1.2 percent). Emission factors for rice cultivation were adapted from IRRI data and are based on the choice of water management regime used. Rice cultivation is the only agriculture source in the Philippines NC that is using local emission factors rather than IPCC default factors.

IPPU CO₂ emissions from cement production and IPPU CO₂ emissions from iron and steel production account for 1.7 percent and 1.5 percent of total national emissions and are estimated using IPCC default emission factors. CH₄ emissions from solid waste disposal account for 1.5 percent of total national emissions. Solid waste disposal emissions are calculated based on several studies (Industrial Efficiency and Pollution Control Project, Environmental Management Strategy, and the JICA-sponsored research on urban waste management) and use an adjusted degradable organic component value.⁷³ The major limitation to the solid waste emission estimates identified in the NC is that the studies are based on the National Capital Region of Metro Manila only and therefore may not be representative of conditions and activities in other parts of the country.

Table 4-10 summarizes the key source categories of the Philippines and the weighted score for emission factor prioritization. Based on the weighted score, improvements to the emission factors related to CO₂ from forest and land use change (both emissions and removals) are the highest priority given their contribution to national emissions and high uncertainty. Carbon dioxide emissions from biomass burning is another high priority sector for emission factor improvement given the limited emission factor data available. CO₂ emissions from mobile combustion, IPPU CO₂ emissions from cement production, and IPPU CO₂ emissions from iron and steel production, and N₂O emissions from manure management are secondary priorities that should be considered for further research. This analysis is based on the 1994 national inventory and additional sources, particularly those affected by population growth, may now be important for emission factor improvement. In particular, emissions from fuel combustion for residential stationary combustion and domestic and industrial waste water may be additional sources to prioritize for further emission factor studies.

Nationally, the development of CSEFs could help improve the accuracy of not only the Philippines national inventory but also help to better track mitigation actions undertaken as part of broader national climate policies and objectives. The Philippines' climate change strategies and action plans are contained in several key documents, including the Philippine Development Plan (2011–2016) released in March 2011,⁷⁴ the National Framework Strategy for Climate Change,⁷⁵ National REDD+ Strategy,⁷⁶ Philippines Strategy for Climate Change Adaptation, and the National Climate Change Action Plan.⁷⁷ Regionally, there is potential to share the good practices and approaches employed by the Philippines in developing specific emission factors for rice cultivation and for changes in forestry and woody biomass.

⁷³ Pg. 23, NC1

⁷⁴ NEDA (2011).

⁷⁵ PCCC (2011).

⁷⁶ DENR (2011).

⁷⁷ PCCC (2010).

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Table 4-10: Emission Factor Framework for the Philippines

Source Category (level)	Sector	Gas	Emissions Estimate (Gg of CO ₂ e-eq.)	% Share of Total National Emissions		% Share of Sector Emissions		Ease of Moving to a Higher Tier Emission Factor	Tier and Emission Factor		Uncertainty with Emission Factor		Total Weight	
				Value: x%	Weight Factor	Value: x%	Weight Factor		Description of Emission Factor	Weight Factor	Descriptio n	Weight Factor		Value
Changes in forest and other woody biomass (removals)	LULUCF	CO ₂	(68,323.0)	23.9%	10	-50%	2	Main source of data on biomass growth rates, densities, and carbon content: Lasco, R.D. and F.B. Pulhin, 1999.	3	Tier 2; CSEFs used.	1	*	3	19
Forest and land use change (emissions)	LULUCF	CO ₂	65,549.0	22.9%	10	48%	2	of data on biomass growth rates, densities, and carbon content: Lasco, R.D. and F.B. Pulhin, 1999.	3	Tier 2; CSEFs used.	1	*	3	19
Biomass (stationary combustion)	Energy	CO ₂	48,490.0	17.0%	8	49%	2	Not described in NCL.	1	Unknown.	3	N/A	3	17
Mobile combustion	Energy	CO ₂	15,801.0	5.5%	4	16%	1	IPCC default values.	2	Tier 1; default IPCC emission factors used.	5	N/A	3	15
Energy industries (stationary combustion)	Energy	CO ₂	15,458.0	5.4%	4	16%	1	IPCC default values.	1	Tier 1; default IPCC emission factors used.	5	N/A	3	14

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Rice cultivations	Agriculture	CH ₄	13,364.4	4.7%	2	40%	2	Adapted from IRRI.	3	Tier 1/2; mix of IPCC and region- specific values.	3	N/A	3	13
Manufacturing industries and construction (stationary combustion)	Energy	CO ₂	8,980.0	3.1%	2	9%	1	IPCC Default values.	1	IPCC default emission factors used.	5	N/A	3	12
Agricultural soils (direct N ₂ O emissions)	Agriculture	N ₂ O	8,680.0	3.0%	2	26%	1	Not described in NCL.	3	Not described in NCL.	3	N/A	3	12
Domestic Livestock (including enteric fermentation and manure management)	Agriculture	CH ₄	7,002.9	2.4%	2	21%	1	Not described in NCL.	3	Not described in NCL.	3	N/A	3	12
Cement (process emissions)	IPPU	CO ₂	4,771.0	1.7%	2	45%	2	IPCC default values.	2	IPCC default emission factors used.	5	N/A	3	14
Iron and steel (process emissions)	IPPU	CO ₂	4,318.0	1.5%	2	41%	2	IPCC default values.	3	Tier 1; default IPCC emission factors used.	5	N/A	3	15

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								Most of the calculations relied on studies such as the Industrial Efficiency and Pollution Control Project and Environmental Management Strategy (IEPC/EMS, 1992) and JICA-sponsored research on urban waste management.						
Solid waste disposal	Waste	CH ₄	4,253.1	1.5%	2	60%	2	Tier 2; CSEFs used.	2	Tier 1; default IPCC emission factors used.	1	N/A	3	10
Manure management	Agriculture	N ₂ O	3,493.7	1.2%	2	11%	1		3		5	N/A	3	14
Commercial/institutional (stationary combustion)	Energy	CO ₂	3,368.0	1.2%	2	3%	1	Not described in NC1.	1	Not described in NC1.	3	N/A	3	10

* Uncertainties include: unknown impact of Philippines soil carbon and biomass growth in abandoned lands, as well as uncertainties in local biomass densities and growth rates. Another central issue of concern is the derivation of forest/non-forest land areas and their temporal changes. Elementary exponential extrapolation was used wherever gaps existed or wherever the administrative classification of forest biomass types (such as old growth dipterocarp forests) did not reflect the reality. The various fates of biomass resulting from the conversion of land were likewise inferred from studies such as the ESMAP survey of the UNDP.

Thailand

Thailand submitted its NC2 to the UNFCCC in 2011. This included a national GHG inventory for 2000. Tier 1 methodologies and default emission factors were primarily used for Thailand's NC2 with the exception of N₂O emissions from animal waste management and GHG emissions from rice cultivation, forest management, and waste management where Tier 2 methodologies were applied.

Thailand has 13 key categories of GHG emissions, approximately half of which are from the energy sector. Energy sources include: CO₂ emissions from stationary combustion for energy industries (19 percent of national emissions); CO₂ emissions from mobile combustion (13 percent); CO₂ emissions from stationary combustion for manufacturing and construction (9 percent); CO₂ emissions from stationary combustion for "other" sectors (3 percent); and fugitive CH₄ emissions from oil and natural gas systems (1 percent). Although the energy sector accounts for 39 percent of the total national emissions, there are no country-specific emission factors available for this sector.

There are three key categories from the LULUCF sector: CO₂ emissions from forest and grassland conversion (13 percent); CO₂ emissions from abandoned managed lands (11.5 percent); and CO₂ removals from changes in woody and forest biomass (4 percent). Dr. Vute Wangwacharakul, the manager for Thailand's NC2, stated that the emission factors for LULUCF are not representative of Thailand's forest types and this should be a priority area for any additional research.⁷⁸

Agricultural sector key categories include: CH₄ emissions from rice cultivation (9 percent); CH₄ emissions from enteric fermentation (2 percent); and N₂O emissions from managed soils (2 percent). The NC2 indicates that there are locally derived emission factors available for this source but the values have not been included in the NC2.⁷⁹ The emissions for enteric fermentation and managed soils were estimated using IPCC default emission factors. Dr. Wangwacharakul indicated that livestock emission factors for both manure management and enteric fermentation are areas for improvement in Thailand.⁸⁰

IPPU CO₂ emissions from cement production is the only industrial process key category and IPCC default emission factors were used to estimate these emissions. Methane emissions from solid waste disposal is the only waste sector key source and local emission factors were applied for this category as well. The NC2 states that these emission factors were derived using the Delphi technique but no additional detail has been provided.

⁷⁸ Expert consultations, Dr. Vute Wangwacharakul. February 11, 2013.

⁷⁹ Pg. 42, NC2.

⁸⁰ Expert consultations, Dr. Vute Wangwacharakul. February 11, 2013.

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Table 4-11 provides a summary of the key source categories for Thailand and a weighted score for each. Based on the weighted score, CO₂ emissions from stationary combustion for energy industries, IPPU CO₂ emissions from cement production, and CO₂ emissions from mobile combustion are high priority sectors for emission factor development. Carbon dioxide emissions/removals from abandoned managed lands, CO₂ emissions/removals from forest and grassland conversion, CO₂ emissions from stationary combustion for manufacturing and construction, CH₄ emissions from enteric fermentation and N₂O emissions from managed soils are other sectors that had high weighted scores.

Some efforts are underway to improve emission factors in Thailand for fossil fuel combustion and wastewater treatment. A number of national initiatives on climate change policy and GHG mitigation in particular could benefit from more accurate emission factors. Thailand's key climate change policies are presented in the National Strategic Plan on Climate Change Management (2008–2012) and the (draft) National Master Plan on Climate Change (2011–2050). Although it did not sign on to the Copenhagen Accord, Thailand is making plans to comply with the requirements of the Durban Decision, including the submission of BURs. Thailand plans to develop both domestically and internationally supported NAMAs that will link to an MRV system.⁸¹ It is already seeking financial support to develop a methodology for NAMA planning in the waste management sector.⁸² Thailand also is developing a voluntary domestic carbon market called T-VER (Thailand Verified Emissions Reduction program), with a tentative launch date in 2013.

⁸¹ Wayuparb (2012).

⁸² Ecofys (2012).

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Table 4-11: Emission Factor Framework for Thailand

Source Category (level)	Sector	Gas	Emissions Estimate (Gg of CO ₂ e-eq.)	% Share of Total National Emissions		% Share of Sector Emissions		Ease of Moving to a Higher Tier Emission Factor		Tier and Emission Factor		Uncertainty with Emission Factor		Total Weight
				Value	Weight	Value	Weight	Description of Emission Factor	Weight Factor	Description	Weight Factor	Value	Weight Factors	
Energy industries (stationary combustion)	Energy	CO ₂	64,241.0	19%	8	40%	2	IPCC default emission factors used.	1	Tier 1: default IPCC emission factors used.		Same as IPCC.	3	19
Mobile combustion	Energy	CO ₂	44,438.7	13%	6	23%	1	IPCC default emission factors used.	2	Tier 1: default IPCC emission factors used.		Same as IPCC.	3	17
Forest and grassland conversion (emissions)	LULUCF	CO ₂	44,234.1	13%	6	46%	2	CSEFs used.	3	Tier 2: CSEFs used.		N/A	2	14
Abandonment of managed lands (removal)	LULUCF	CO ₂	(39,022.5)	11%	6	-40%	2	CSEFs used.	3	Tier 2: CSEFs used.		N/A	2	14
Manufacturing industries and construction (stationary combustion)	Energy	CO ₂	30,305.8	9%	4	19%	1	IPCC default emission factors used.	1	Tier 1: default IPCC emission factors used.		Same as IPCC.	3	14
Rice cultivations	Agriculture	CH ₄	29,939.7	9%	4	53%	2	CSEFs used.	3	Tier 2: CSEFs used.		N/A	2	12
Cement (process emissions)	IPPU	CO ₂	15,731.5 ⁸	5%	4	96%	3	IPCC default emission factors used.	2	Tier 1: default IPCC emission factors used.		Same as IPCC.	3	17

⁸³ 98 percent of total emissions from mineral production of 16,052.6 Gg.

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N/A: Not available

Vietnam

Vietnam submitted its NC2 in 2010 with reported emissions for 2000. The national GHG inventory included in the NC2 was prepared in accordance with the Revised 1996 IPCC Guidelines and primarily used default emission factors. There are 19 key categories for Vietnam, with six from LULUCF (CO₂ removals from forest land remaining forest land, CO₂ and CH₄ emissions from forest soils, CO₂ emissions from forest and grassland conversion, CO₂ removals from abandoned managed lands, and CH₄ emissions from forest and grassland conversion), four from agriculture (CH₄ emissions from rice cultivation, direct N₂O emissions from agricultural soils, CH₄ emissions from enteric fermentation, and CH₄ emissions from manure management), six from energy (CO₂ emissions from manufacturing and construction, CO₂ emissions from mobile combustion, CO₂ emissions from liquid fuels, CO₂ emissions from solid fuels, fugitive CO₂ emissions from oil and natural gas, and CO₂ emissions from commercial stationary combustion), two from industrial processes (CO₂ emissions from iron and steel and CO₂ emissions from cement production), and one from waste (CH₄ from solid waste disposal).

Four of the top five key categories are from LULUCF: CO₂ removals from changes in forest and woody biomass (16 percent); CO₂ emissions from soils (15.5 percent); CO₂ emissions/removals from forest and grassland conversion (13.4 percent); and CH₄ emissions from soils (6.1 percent). CO₂ removals from abandoned managed lands and CH₄ emissions from forest and grassland conversion each contribute 2.4 and 1.0 percent, respectively. LULUCF emissions and removals are estimated using Tier 1 default factors and methodologies and account for over half of Vietnam's total national emissions.

Emissions from the agriculture section include: CH₄ emissions from rice cultivation (12.4 percent of total emissions); N₂O emissions from managed soils (4.7 percent); CH₄ emissions from enteric fermentation (2.6 percent); and CH₄ emissions from manure management (1.1 percent). Local emission factors were used to estimate emissions from rice cultivation in North Vietnam. These emission factors, for paddies with organic and inorganic fertilizers, were calculated from local methane measurement experiments conducted in 1998 and 1999. Paddies from the south of Vietnam primarily use inorganic fertilizers and IPCC default emission factors were used to estimate emissions from this region. Representatives from the Ministry of Agriculture and Rural Development (MARD), the Research Center for Climate Change and Sustainable Development, and the Ministry of Industry and Trade (MOIT) indicated that additional CH₄ measurement experiments were necessary in the South of Vietnam as this is an important rice cultivation region in the country. Livestock emission factors including enteric fermentation and manure management have also been identified as a key area for improvement. Representatives from the Ministry of Natural Resources and Environment (MONRE) and the Research Center for Climate Change and Sustainable Development have indicated that the emission factors for livestock in Vietnam should be lower than the default factors from the IPCC; the current estimates are not representative for the country.

Key sources of CO₂ emissions from the energy sector include: stationary combustion for manufacturing and construction industries (5.0 percent of national emissions); mobile combustion (3.9 percent); liquid fuels (2.0 percent); solid fuels (1.4 percent); fugitive CH₄ emissions from oil and natural gas systems (1.0 percent); and stationary combustion for commercial energy (1.0 percent). Emissions from liquid, solid, and gaseous fuel were reported as a single value ("energy industries") in the NC2. For the purpose of this analysis, "energy industries" was subdivided based on emissions by fuel type data reported in

⁸⁴ Table 2.1, NC2.

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2000.⁸⁴ Energy sector emissions for Vietnam account for approximately 14 percent of national emissions in 2000, but the NC2 projects that energy sector emissions will grow to over 91 percent of total inventory emissions by 2030. All energy sector emissions are currently estimated using IPCC default emission factors. Some efforts have been made to develop local factors for coal combustion and coal mining but these were not robust enough to include in the NC2. Representatives from the MONRE, the Vietnam Academy of Science and Technology, and MOIT indicated that coal combustion and coal mining is a priority for future emission factor development. Coal is not completely combusted in power plants in Vietnam, making estimates of GHG emission for this fuel highly uncertain when default emission factors are used.

IPPU CO₂ emissions from cement production and IPPU CO₂ emissions from iron and steel production account for 3 percent of total national emissions. CH₄ emissions from solid waste disposal account for 1.9 percent of total emissions. Industrial process and waste emissions were calculated using IPCC default emission factors. Improvements in the emission factors for these sectors are not a high priority given their relatively small contributions to national GHG emissions and removals.

Table 4-12 provides a summary of the key source categories in Vietnam and a prioritization of sectors for emission factor development. Based on a weighted score, LULUCF sectors, particularly CO₂ removals from forest lands remaining forest lands, CO₂ removals/emissions from soils, and CO₂ emissions from forest land converted grassland, are the highest priority for emission factor development. IPCC default factors are currently being used to estimate these emissions thus estimates have a high level of uncertainty. Other priority areas include CH₄ emissions from rice cultivation, CH₄ emissions from solid waste disposal, and IPPU CO₂ emissions from cement production.

Improved emission factors could help Vietnam on a number of climate policy fronts, particularly to track GHG mitigation actions. MONRE led the drafting of a national Climate Change Strategy approved in late 2011. Parallel to these efforts and at the request of the Prime Minister, the Ministry of Planning and Investment (MPI) is leading an inter-ministerial process to develop a national Green Growth Strategy extending to 2030. The strategy involves a range of other ministries, particularly the MOIT, and is broader than a LEDS but includes many of the key LEDS elements. In addition to drafting the Green Growth Strategy, the MPI is incorporating climate change indicators into national socioeconomic plans. It is undertaking research on low-carbon development options (through the CIEM) to support future implementation of the Green Growth Strategy.

Efforts at improving emission factors should be coordinated with other programs such as those of IGES/JICA and LEAF.

⁸⁴ Table 2.1, NC2.

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Table 4-12: Emission Factor Framework from Vietnam

Source Category (level)	Sector	Gas	Emissions Estimate (Gg of CO ₂ e-yr)	% Share of Total National Emissions		% Share of Sector Emissions		Ease of Moving to a Higher Tier Emission Factor		Tier and Emission Factor		Uncertainty with Emission Factor		Total Weight
				Value: x%	Weight Factor	Value: x%	Weight Factor	Description of Emission Factor	Weight Factor	Description	Weight Factor	Value	Weight Factor	
Forest land remaining forest land (removals)	LULUCF	CO ₂	(49,830.2)	16.0%	8	-30%	1	IPCC default values used for majority of sectors.	3	Tier 1; default IPCC emission factors used.	5	Same as IPCC.	3	20
Forest soils (emissions)	LULUCF	CO ₂	46,943.8	15.5%	8	28%	1	IPCC default values used for majority of sectors.	3	Tier 1; default IPCC emission factors used.	5	Same as IPCC.	3	20
Forest and grassland conversion (emissions)	LULUCF	CO ₂	40,665.2	13.4%	6	24%	1	IPCC default values used for majority of sectors.	3	Unclear.	3	Same as IPCC.	3	16
Rice cultivations	Agriculture	CH ₄	37,429.8	12.4%	6	58%	2	CH ₄ emission factors in the North were calculated from local methane measurement experiment. ⁸⁵ IPCC default factors used in the South.	3	Tier 1 South / Tier 2 North	3	Same as IPCC or N/A.	2	16

⁸⁵ Expert consultations conducted by Khanh Nguyen Quoc with Vietnamese government officials, 23 March 2013.

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Forest soils (removals)	LULUCF	CH ₄	(18,588.2)	6.1%	4	-11%	1	IPCC default values used for majority of sectors.	3	Tier 1; default IPCC emission factors used.	5	Same as IPCC.	3	16
Manufacturing industries and construction (stationary combustion)	Energy	CO ₂	15,020.4	5.0%	4	28%	1	IPCC default values used for majority of sectors.	1	Tier 1; default IPCC emission factors used.	5	Same as IPCC.	3	14
Agricultural soils (direct N ₂ O emissions)	Agriculture	N ₂ O	14,219.7	4.7%	2	22%	1	IPCC default values used for majority of sectors.	3	Tier 1; default IPCC emission factors used.	5	Same as IPCC.	3	14
Mobile combustion	Energy	CO ₂	11,886.0	3.9%	2	23%	1	IPCC default values used for majority of sectors.	2	Tier 1; default IPCC emission factors used.	5	Same as IPCC.	3	13
Enteric fermentation	Agriculture	CH ₄	7,730.5	2.6%	2	12%	1	IPCC default values used for majority of sectors.	3	Tier 1; default IPCC emission factors used.	5	Same as IPCC.	3	14
Abandonment of managed lands (removals)	LULUCF	CO ₂	(7,330.3)	2.4%	2	-4%	1	IPCC default values used for majority of sectors.	3	Tier 1; default IPCC emission factors used.	5	Same as IPCC.	3	14
Cement (process emissions)	IPPU	CO ₂	6,629.1	2.2%	2	66%	3	IPCC default values used for majority of sectors	2	Tier 1; default IPCC emission factors used.	5	Same as IPCC.	3	15

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Energy industries- liquid fuel (stationary combustion) ⁸⁶	Energy	CO ₂	6,190.5	2.0%	2	12%	1	IPCC default values used for majority of sectors.	1	Tier 1; default IPCC emission factors used.	Same as IPCC.	3	12
Solid waste disposal	Waste	CH ₄	5,596.9	1.9%	2	71%	3	IPCC default values used for majority of sectors	2	Tier 1; default IPCC emission factors used.	Same as IPCC.	3	15
Energy industries- solid fuel (stationary combustion) ⁸⁷	Energy	CO ₂	4,346.7	1.4%	2	8%	1	IPCC default values used for majority of sectors	1	Tier 1; default IPCC emission factors used.	Same as IPCC.	3	12
Manure management	Agricultur e	CH ₄	3,447.4	1.1%	2	5%	1	IPCC default values used for majority of sectors.	3	Tier 1; default IPCC emission factors used.	Same as IPCC.	3	14
Fugitive emissions from - oil and natural gas	Energy	CO ₂	3,170.0	1.0%	2	6%	1	IPCC default values used for majority of sectors.	3	Tier 1; default IPCC emission factors used.	Same as IPCC.	3	14
Commercial (stationary combustion)	Energy	CO ₂	2,957.6	1.0%	2	6%	1	IPCC default values used for majority of sectors.	1	Tier 1; default IPCC emission factors used.	Same as IPCC.	3	12
Forest and grassland conversion (emissions)	LULUCF	CH ₄	2,946.3	1.0%	2	2%	1	IPCC default values used for majority of sectors.	3	Tier 1; default IPCC emission factors used.	Same as IPCC.	3	14

⁸⁶ CO₂ emissions from “energy industries” is reported as 11,174.15 Gg in the NC2. The proportion of emissions resulting from liquid fuel combustion is approximated using fuel type data from Table 2.1 of the NC2. According to Table 2.1, 55.4 percent of CO₂ emissions were from oil sources. CO₂ emissions from liquid fuel used in stationary combustion is estimated as (11,174.15 Gg CO₂) × (55.4%) = 6,190.5 Gg CO₂.

⁸⁷ CO₂ emissions from “energy industries” is reported as 11,174.15 Gg in the NC2. The proportion of emissions resulting from solid fuel combustion is approximated using fuel type data from Table 2.1 of the NC2. According to Table 2.1, 38.9 percent of CO₂ emissions were from coal sources. CO₂ emissions from solid fuel used in stationary combustion is estimated as (11,174.15 Gg CO₂) × (28.9%) = 4,346.74 Gg CO₂.

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Iron and Steel (process emissions)	IPPU	CO ₂	2,535.6	0.8%	2	25%	IPCC default values used for majority of sectors.	3	Tier 1; default IPCC emission factors used.	5	Same as IPCC.	3	14
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LEAD Program Emission Factor Improvement Report

5. SHORT-LIVED CLIMATE POLLUTANTS

The goal of this section is to provide an objective analysis that identifies Short-lived Climate Pollutants (SLCP) emission factors to be considered in the recommendation of up to six specific emission factors on which to ultimately provide training and technical assistance to LEAD countries. The research team adopted the following systematic approach to conduct this analysis:

1. Identified SLCPs for consideration in this analysis informed by reviewing current definitions used by the international community;
2. Reviewed UNFCCC national communication reports and literature to identify SLCP inventories for LEAD partner countries;
3. Analyzed Southeast Asian SLCP inventories to determine key emitting source categories and, as possible, identified major country emitters;
4. Of the identified source categories, investigated the accuracy of available emission factors based on literature review and expert consultation; and
5. Consulted with experts to review results and compile additional feedback.

See Annex III for additional details of the information collected and used to inform this analysis.

5.1 Evaluation Results

The SLCP evaluation considered the following for each SLCP based on the information described in the Objectives section:

- *KCA*: Identified which sectors and countries are the greatest emitters of each SLCP. This effort helped streamline the recommendations by focusing on the key geographic areas/categories.
- *Emissions factor analysis*: Explored emission factors currently used by global and regional emission inventories and the uncertainties associated with the emission factors. This analysis was supplemented by expert interviews and literature review. This analysis provides a survey of the current status of emission factors.

The remainder of this section provides the analyses above for each SLCP (i.e., black carbon, tropospheric ozone, and HFCs) and a summary of the findings and recommendations.

Black Carbon

Black carbon emissions are the result of incomplete combustion of fossil fuels or biogenic fuels such as wood. Black carbon contributes to regional warming and is a known air pollutant that impairs human health (see text box entitled *Climate Impacts of SLCP*). Unlike GHGs or hydrofluorocarbons, there is no standard global warming potential (GWP) for black carbon. Studies have calculated 100 year GWPs for black carbon ranging from 330 to 2,140.⁸⁸ The interaction of black carbon (and other co-emitted aerosol species) with clouds is especially poorly quantified, and this factor is key to any attempt to estimate the net climate impacts of black carbon. At the global scale, the black carbon inventories

⁸⁸ USEPA (2012).

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demonstrate an underestimation of black carbon concentrations compared to observations but it is unclear what is driving that underestimate. Inadequate activity level data, inadequate emission factors, or missing source categories such as dung (which is used as a biofuel) are potentially driving that underestimation.⁸⁹ Currently, Asia as a whole accounts for 40 percent of worldwide black carbon emissions, with Southeast Asia representing approximately 45 percent of Asian emissions.⁹⁰

Globally, residential/domestic sources and open biomass burning are the largest source category contributors to total black carbon emissions. This is consistent with emissions from Southern Asia where residential/domestic burning and open biomass burning contribute 73 percent to the total emissions of black carbon (see Figure 1).⁹¹ In Southern Asia, the residential/domestic source category includes the combustion of solid biomass (wood, dung) and coal in cook stoves and heating stoves.⁹² Open biomass burning includes forest fires, land clearing by fire activity, and burning of agricultural waste.⁹³ Other contributing source categories include fuel combustion in the industry and transport sectors which contribute 14 percent and 13 percent of black carbon emissions, respectively. The industrial sector encompasses the burning of coal and petroleum products, and the transport sector includes diesel fuel use.⁹⁴

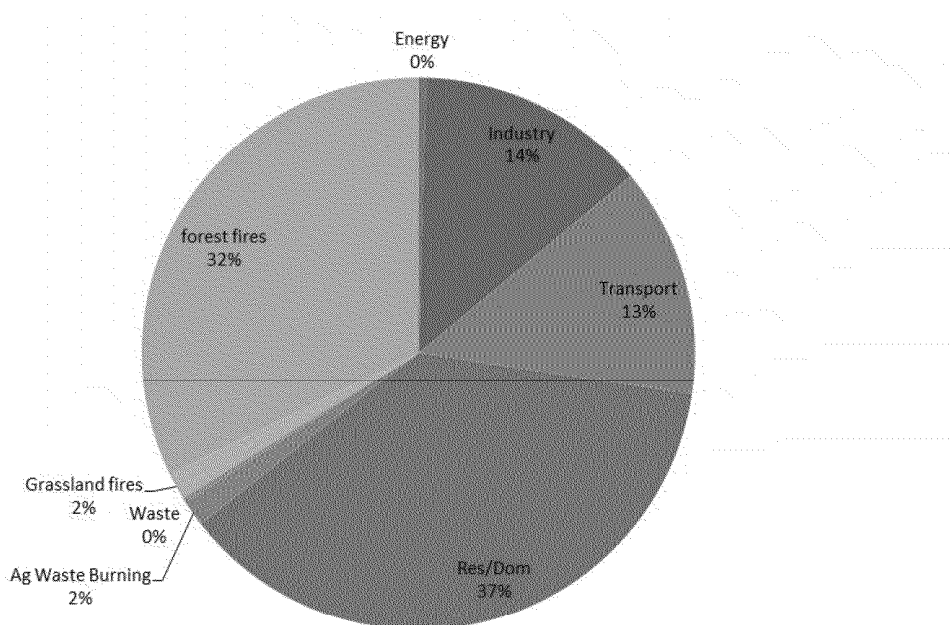


Figure 1: Percent contribution of black carbon emissions in Southern Asia by source category for 2000.⁹⁵

India and Indonesia are significant contributors to regional black carbon emissions contributing

⁸⁹ Larmarque 2013; Granier *et. al.* (2011).

⁹⁰ Larmarque *et al.* (2010).

⁹¹ For purposes of this report, Southern Asia includes India, Thailand, Nepal, Philippines, Vietnam, Malaysia, Papua New Guinea, Cambodia, Indonesia, Malaysia, Singapore, Laos, and Myanmar.

⁹² USAID (2011).

⁹³ Open biomass burning also emits large quantities of organic carbon which cause a cooling, thereby negating a large amount of the warming associated with black carbon (USAID 2011).

⁹⁴ USAID (2011).

⁹⁵ Larmarque *et. al.* (2010).

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approximately 67 percent to total Southeast Asia emissions (see Figure 2).⁹⁶ It is unclear how close the percent contribution by country is to a true representation of current emissions (i.e., is the current representation an artifact of a few countries having capabilities to realistically portray activity levels and emissions while other countries do not have the capability?).

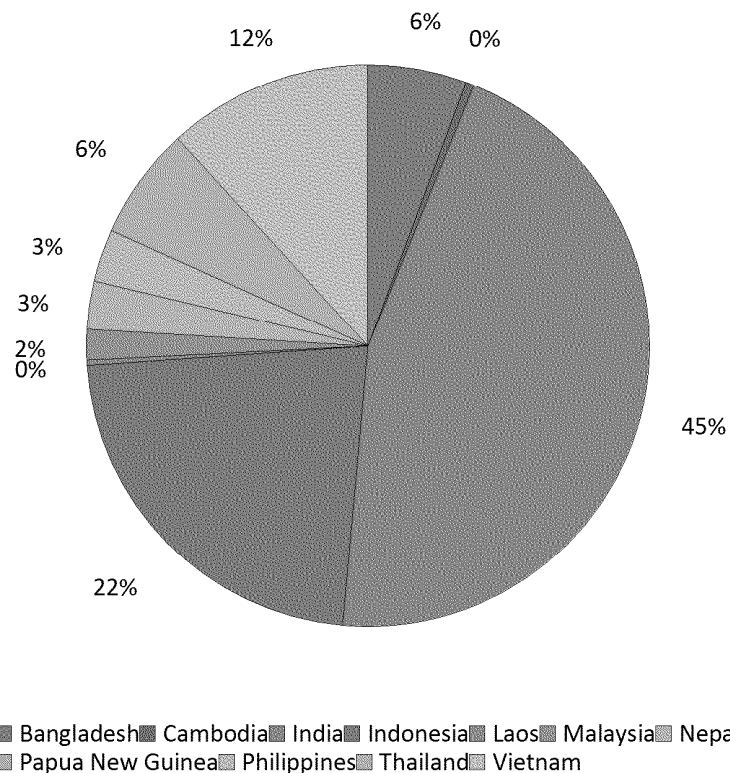


Figure 2: Percent contribution of black carbon by country.⁹⁷

⁹⁶ Zhang *et al.* (2009). For purposes of this report, Southeast Asia is defined as Bangladesh, Cambodia, India, Indonesia, Laos, Malaysia, Nepal, Papua New Guinea, Philippines, Thailand, and Vietnam.

⁹⁷ Zhang *et al.* (2010).

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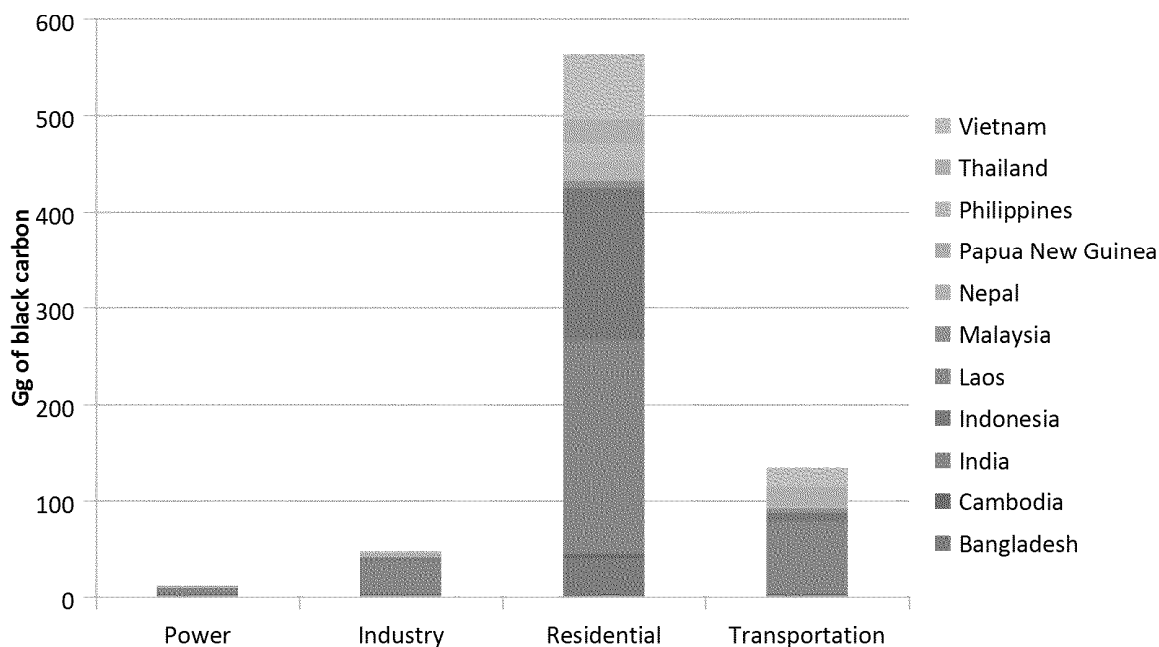


Figure 3: Total contribution of black carbon emissions by source category.⁹⁸

In general, for Southeast Asia, emissions provided by the National Aeronautics and Space Administration (NASA) Intex-B inventory are estimated using activity levels and emission factors on a source-by-source basis. The uncertainty associated with the emission factors across source categories is discussed below. In general, there is substantial room for improvement of emission factors for combustion technologies in Southeast Asia that are not in use in the United States and Europe.⁹⁹

Domestic/residential. Dickerson found minimal uncertainty in South Asia in domestic/residential source emissions in comparison to the other source categories.¹⁰⁰ That said, a few key technologies are considered important contributors to black carbon emissions, and would benefit from further research into producing appropriate emission factors.

- **Cook stoves, heating stoves, and boilers.** Accurately portraying black carbon emissions from cookstoves can be problematic due to the variety of cookstoves available and the corresponding black carbon emission factors and activity levels. For example, there are more than 30 different types of cookstoves in use in India alone.¹⁰¹ In addition, there is prevalent use of emission factors provided in the literature during the early 1980s, which tends to suggest higher than actual black carbon emissions. Investigating the regional diversity of cook stoves would be beneficial to increasing the accuracy in estimating emissions from this important black carbon emission source. The black carbon emission factors for residential heating stoves tend to also be based on emissions measurements from the 1980s. A recent study suggests emission factors are much lower, though the study does not take into account fuel addition or exhaust characteristics.¹⁰²

⁹⁸ Zhang *et al.* (2010).

⁹⁹ Bond (2013).

¹⁰⁰ Dickerson *et al.* (2002).

¹⁰¹ Bond *et al.* (2007).

¹⁰² Bond *et al.* (2007).

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- **Coal-burning cookstoves or open cooking fires.** Emissions of black carbon from coal-burning cookstoves or open cooking fires are considered less important than heating stoves, but the uncertainty is considered high. Emission factors currently used may greatly underestimate the actual emissions.¹⁰³ The NASA Intex-B inventory applies a uniform emission factor for a given fuel across the entire cookstove sector, based on the method presented in Transport and Chemical Evolution over the Pacific (TRACE-P) inventory.¹⁰⁴ However, black carbon emissions from residential coal combustion, for example, can vary considerably depending on coal type (bituminous versus anthracite) and combustion type (raw coal versus briquette).

Open biomass burning. The NASA Intex-B inventory relies on emission factors presented in Streets' 2003 study.¹⁰⁵ Though there is a lot of uncertainty regarding open biomass burning in Southeast Asia, the emission factors do not appear to be the limiting factor in the uncertainty of the estimate.¹⁰⁶ Important work has been done through laboratory studies to investigate emission factors associated with the combustion from different vegetation types.¹⁰⁷ The challenge in accurately capturing emissions from this sector is related to accurately interpreting satellite data of fires. Researchers are challenged by identifying the vegetation being burnt and the environmental conditions under which it is being burnt; the potential variations in this interpretation of satellite data can lead to a difference in black carbon emissions estimates of a factor of two compared to observations.¹⁰⁸ One aspect of fire emission factors that may not be well represented is a seasonal component which can change the moisture content in the fuel and affect the amount of black carbon emitted.¹⁰⁹

Industry. There is limited information available on fossil fuel usage in industrial sources in many parts of Southeast Asia, and, for example, most industrial sector fuel combustion inventories refer to the International Energy Agency (IEA) database for activity levels. For emission factors for industrial sector fossil fuel combustion, the Southeast Asia inventory uses data provided by Streets and Ohara.¹¹⁰ Though industrial source fuel combustion contributes less black carbon emissions than emissions from residential/domestic fuel combustion and open biomass burning, Dickerson suggests it represents the largest amount of uncertainty in estimating black carbon emissions.¹¹¹ For example, industrial source emission factors developed from stack emissions measurements specific to Southeast Asia are not available, making this source category an important area for future research.¹¹² Of the industrial source categories, accurately portraying black carbon emissions from brick kilns is considered a concern in producing robust regional black carbon emissions estimates.

- **Brick kilns.** In areas including Southeast Asia, the production of bricks has increased in recent decades in response to growing urbanization and increasing demand for construction

¹⁰³ Granier *et al.* (2011)

¹⁰⁴ Zhang *et al.* (2009)

¹⁰⁵ Streets *et al.* (2003)

¹⁰⁶ Larmarque (2013)

¹⁰⁷ *Ibid.*

¹⁰⁸ *Ibid.*

¹⁰⁹ Bond *et al.* (2007)

¹¹⁰ Streets *et al.* (2001); Streets *et al.* (2003); Ohara *et al.* (2007)

¹¹¹ Dickerson *et al.* (2002)

¹¹² Bond (2013)

¹¹³ USEPA (2012).

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materials.¹¹³ The diversity of emission factors across different types of brick kilns, such as bull's trench, clamp, and intermittent downdraught kilns, is not well represented. Fuels may vary from low-quality coal and firewood to waste fuels such as scrap tires.¹¹⁴ For example, Bond uses an emission factor for black carbon emissions from brick kilns that is an average of the heating stove and stoker furnace black carbon emission factors but suggests that there may be a 200 percent uncertainty in this estimate. These sources would benefit from additional work investigating appropriate emission factors.¹¹⁵

Transport. The black carbon emissions from mobile combustion (transport) are increasing in Southeast Asia largely due to the dramatic increase in traffic volume.¹¹⁶ There are considerable challenges to accurately estimating black carbon emissions from transport due to the lack of data regarding emissions from individual vehicle types, and the numbers and types of vehicles on the road in each country.¹¹⁷ In fact, Dickerson suggests this source category represents another large source of uncertainty, second to fuel combustion in the industry sector. The Southeast Asia inventory uses emission factors for vehicles informed by the MOBILE model.^{118, 119}

- **Two stroke engines.** Though there are no observations available to support the emission factors, two stroke engines tend to be high emitters of black carbon because the intake of fresh air and fuel occurs simultaneously with the exhaust of combustion products, so unburned fuel and lubricating oil can easily escape from the cylinder.

It is clear that there is significant uncertainty in emission factors across source categories. To streamline research efforts, two immediate areas of improvement might include (1) emission factors for brick kilns by kiln type and fuel, and (2) emission factors for cook stoves by stove type and fuel. Emissions from these sources are important to capture in Southeast Asian inventories but, given the diversity, can be challenging to accurately portray. A third black carbon emission source to consider is transport, particularly the prevalent two-stroke diesel-fueled engines in the region.

Tropospheric Ozone

Tropospheric ozone is a gas that is not directly emitted into the Earth's atmosphere, but is formed in the atmosphere from the chemical reactions of other gases. These ozone precursors include: carbon monoxide (CO), non-methane volatile organic compounds (NMVOCs), CH₄, and NO_x. Over the last century, the global rise of methane emissions is responsible for about two-thirds of the increase in tropospheric ozone.¹²⁰ As CH₄ emissions are considered earlier in this report, this analysis will focus on the other three precursors discussed below. Tropospheric ozone, though important in air quality, plays a lesser role in affecting regional climate as compared to black carbon.¹²¹

¹¹³ USEPA (2012).

¹¹⁴ *Ibid.*

¹¹⁵ Bond *et al.* (2007) – this is done as the brick kiln has similar combustion as to heating stoves or stokers but without proper airflow or a chimney to enhance burnout.

¹¹⁶ UNEP (2010).

¹¹⁷ SLOSS (2012).

¹¹⁸ Dickerson *et al.* (2002)

¹¹⁹ EPA's MOBILE vehicle emission factor model is a software tool for predicting gram per mile emissions of hydrocarbons, carbon monoxide, oxides of nitrogen (NO_x), carbon dioxide, particulate matter (PM) and air toxics from cars, trucks, and motorcycles under various conditions.

¹²⁰ IGSD (2012) *citing* UNEP/WMO (2011).

¹²¹ Larmarque (2013).

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Carbon Monoxide

Carbon monoxide is not considered as critical as NO_x as a precursor in ozone formation. It is clear that CO emission estimates from stationary and mobile combustion sources are inaccurate, but since it is not considered a main driver to tropospheric ozone, it has not been given as much attention as NO_x emission factors.¹²²

Figure A-III 2 in Annex III: Short-Lived Climate Pollutant Additional Information illustrates estimated CO emissions for the year 2000 across Asia. A few countries, such as India, are illustrated as significant emitters. The combined emissions from India and Indonesia are 73 percent of the total Southeast Asia emissions (see Figure 4). Carbon monoxide emissions for Asia are projected to increase by 12 percent from 2000 to 2020.¹²³

For Southeast Asia, the residential combustion (54 percent) and transportation (mobile combustion) (37 percent) sectors are the main contributors to total CO emissions, followed by the industry sector (9 percent) (see Figure 4). Open biomass burning, which is estimated to contribute about 24 percent to total CO emissions in Asia, is not accounted for in this figure.¹²⁴

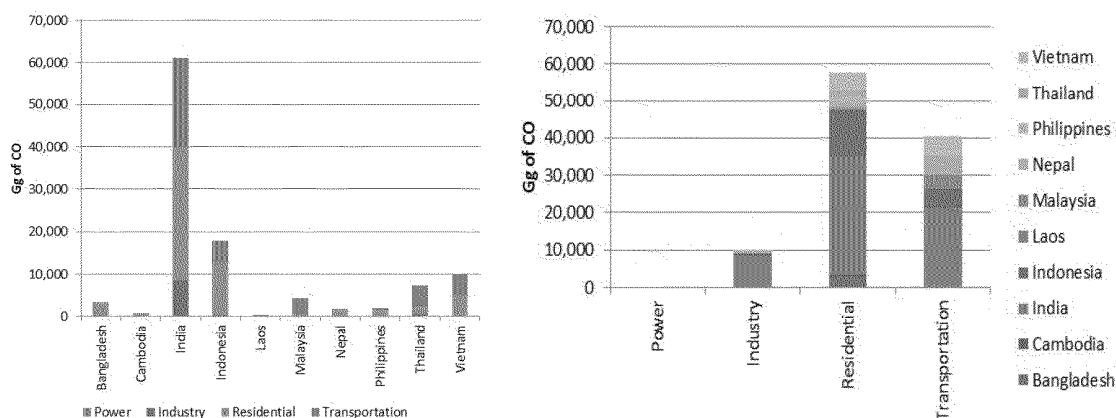


Figure 4: Contribution of CO by country and source category (figure on the left), and contribution of CO by source category and country (figure on the right).¹²⁵

For Southeast Asia, there is an overall 214 percent uncertainty for CO emissions based on a 95 percent confidence interval.¹²⁶ According to Dickerson, biofuel combustion CO emissions estimates are considered reliable for Southern Asia, but biomass burning is poorly understood.¹²⁷ It is unclear if this uncertainty is associated with accurately representing the activity rates and/or the emission factors or both. Dickerson also found that motorcycles contribute substantially, 12 percent, to total Southern Asian CO emissions. As motorcycle CO emissions may also contribute to black carbon concentrations, this could be an important source category to consider for further analysis.

The Southeast Asia inventory uses CO emission factors provided by Streets for vehicles and industrial

¹²² Bond *et al.* (2007); Granier *et al.* (2010).

¹²³ Ohara *et al.* (2007).

¹²⁴ Streets *et al.* (2003).

¹²⁵ Zhang *et al.* (2010).

¹²⁶ Streets *et al.* (2003).

¹²⁷ Dickerson *et al.* (2002).

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process fuel combustion emissions; when available, industrial process and vehicle emission controls and vehicle age profiles are taken into account. For coal combustion by power plants, by industry, and by the residential sector, the CO inventory relies on Streets' 2006 data. Residential coal combustion, however, applies a different emission factor of 150 kg CO/t coal (close to the average emission factor for hand-feed stokers provided by Streets and the maximum value for coal stoves provided by Zhang).¹²⁸

Given this pollutant is not considered a primary driver to tropospheric ozone formation, at this point and in comparison to the other SLCPs and contributors, investigating CO emission factors is not recommended for prioritized research, except in correspondence with investigation of black carbon emission factors from the same source categories, e.g., for motorcycles.

Non-Methane Volatile Organic Compounds

NMVOCs comprise a number of individual species. In the TRACE-P inventory, there are 19 categories of NMVOCs dependent on chemical reactivity and functional groups.¹²⁹ More recent work estimated individual NMVOC species emissions by applying a state-of-the-art source profile database to each source category.¹³⁰ Due to the complexities in estimating and validating the individual NMVOC species and emissions sources, this is an area of continued research.

Figure A-III. 3 in Annex III: Short-Lived Climate Pollutant Additional Information shows the hot spots of NMVOC emissions in Asia using a 2000 inventory. And as with CO, India (43 percent) and Indonesia (27 percent) are the greatest emitters of NMVOC across the Southeast Asian countries. NMVOC emissions for Asia are projected to increase by 99 percent from 2000 to 2020.¹³¹ For Southeast Asia, residential fuel combustion (48 percent) and transport (mobile combustion) (37 percent) contribute the greatest amount to total NMVOC emissions. For Southeast Asia, there is a 218 percent uncertainty for NMVOC emissions based on a 95 percent confidence interval.¹³²

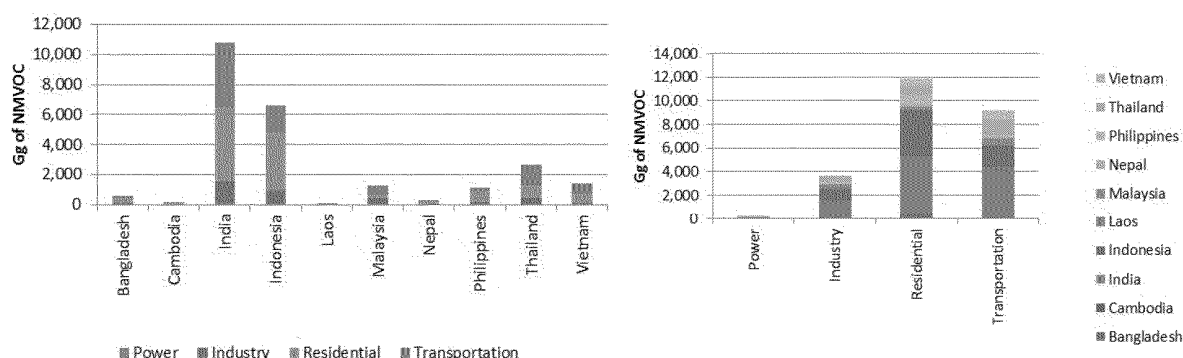


Figure 5: Contribution of NMVOC by country and source category (figure on the left), and contribution of NMVOC by source category and country (figure on the right).¹³³

¹²⁸ Zhang et al. (2009); Ohara et al. (2007).

¹²⁹ Zhang et al. (2006).

¹³⁰ *Ibid.*

¹³¹ Ohara et al. (2007)

¹³² Streets et al. (2003)

¹³³ Zhang et al. (2009).

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Many inventories of NMVOCs do not provide full speciation but are estimated across all NMVOC species or lumped into the estimate for total VOCs, thereby providing a total NMVOC (or a total VOC) emissions estimate. However, in order to accurately simulate the creation of tropospheric ozone and better understand the NMVOC emission sources, it is important that the atmospheric observations of total NMVOC concentrations are speciated to then disaggregate the NMVOC mix that is being emitted. There is a possibility that two campaigns over Southeast Asia funded by the National Oceanic and Atmospheric Administration (NOAA), National Science Foundation (NSF), and the National Center for Atmospheric Research (NCAR) may occur shortly to better understand the VOC mix, though this is dependent on funding. This work would greatly enhance the capacity for understanding which NMVOC species contribute significantly to the total NMVOC concentrations, thereby assisting in determining which NMVOC source categories should be further reviewed.¹³⁴

Additional work in developing more robust NMVOC emission factors should likely continue after the pending research in understanding the NMVOC species in the atmosphere is completed.

Nitrogen Oxides

Figure A-III. 4 in Annex III: Short-Lived Climate Pollutant Additional Information illustrates the variability of NO_x emissions across the region. Four countries represent 90 percent of the Southeast Asia NO_x emissions: India (47 percent), Indonesia (15 percent), Malaysia (16 percent), and Thailand (12 percent). In Southeast Asia, transportation (39 percent), power (35 percent), and industry (17 percent) are the primary NO_x emissions contributors. For Southeast Asia, there is a 92 percent uncertainty for NO_x emissions based on a 95 percent confidence interval.¹³⁵ NO_x emissions for Asia are projected to increase by 44 percent from 2000 to 2020.¹³⁶

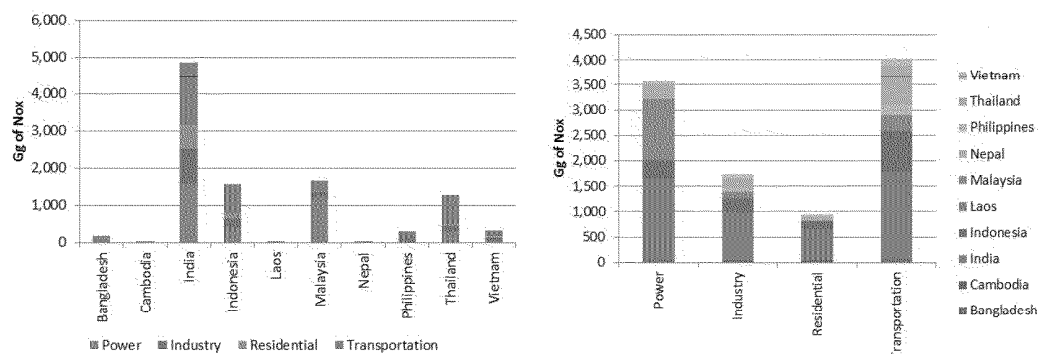


Figure 6: Contribution of NO_x by country and source category (figure on the left), and contribution of NO_x by source category and country (figure on the right).¹³⁷

For automobile sources, several countries identify emission factors dating to 1995 (China, South Korea, Taiwan, Thailand, Philippines, Indonesia, and India). Furthermore, information pertaining to the sources of the emission factors was not provided in the literature.¹³⁸ NO_x emission factors for non-automobile sources are provided by Kato, AP-42, the 2006 IPCC Guidelines, the EMEP/CORINAIR Guidebook, Streets,

¹³⁴ Lamarque (2013)

¹³⁵ Streets *et al.* (2003)

¹³⁶ Ohara *et al.* (2007)

¹³⁷ Zhang *et al.* (2009).

¹³⁸ Ohara *et al.* (2007)

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and Zhang.¹³⁹ Current emission controls by country are then reflected in updated emission factors and removal efficiencies (e.g., national regulations of NO_x emissions from electric power plants and industry sectors).

Though there is some uncertainty associated with the NO_x emissions estimates (including the activity rates and emission factors), these emissions estimates are considered to be relatively accurate compared to estimates for other pollutants. It is necessary, however, that these emission factors continue to be monitored and updated by country to reflect advances in technology and application of any new emission controls.¹⁴⁰

Hydrofluorocarbons

Hydrofluorocarbons are man-made substances that have been introduced into commercial use as substitutes for chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs). HFCs do not deplete the ozone layer and have been used as a substitute for CFCs and HCFCs to comply with the provisions of the Montreal Protocol. Like the ozone-depleting substances (ODSs) that they replace, HFCs are potent greenhouse gases that trap infrared radiation in the atmosphere. Different HFCs vary in their potential to impact the climate. HFC-134a, commonly used in domestic, commercial, industrial, and transport air conditioning and refrigeration, has an atmospheric lifetime of approximately 13 years and a GWP of 1,370.¹⁴¹ HFC-1234yf exists in the atmosphere for less than two weeks and has a GWP of 4.¹⁴² Although their current contribution to climate radiative forcing is less than one percent of all other GHG combined, HFCs have the potential to have a much larger climate impact as more countries phase out CFCs and HCFCs in favor of HFCs.¹⁴³

HFCs are widely used in various applications. The United Nations Environment Program (UNEP) estimates that worldwide, 55 percent of HFCs are used in domestic, commercial, and industrial refrigeration, and air conditioning; 24 percent is used in mobile air conditioning; 11 percent is used for production of foam products; and the remainder is used for aerosols (5 percent), fire suppression (4 percent), and as solvents (1 percent).¹⁴⁴ The use of HFCs is increasing rapidly due to population growth and economic development in regions such as Southeast Asia. At the global scale, consumption of HFC-134a, the most abundantly used HFC, increased by approximately 10 percent between 2006 and 2010. In emerging economies such as India, the growth of HFC-134a consumption is even greater as air conditioning markets have increased by over 20 percent between 1994 and 2006.¹⁴⁵ By 2050, HFCs are projected to exceed the historical peak levels of CFC consumption and result in an increase in radiative forcing by up to 0.4 Watts per square meter (W/m²) relative to 2000.¹⁴⁶

There are currently limited inventory data available for HFCs consumption in Southeast Asian countries. The NC2 from Malaysia and India provide estimates of HFC-related emissions, but limited information about the methodology, specific gases, or emission factors used is available. Sharma discusses the 2007

¹³⁹ Kato *et al.* (1991); AP-42, the 2006 IPCC Guidelines; EMEP/CORINAIR Guidebook; Streets *et al.* (1998) and Zhang *et al.* (2000)

¹⁴⁰ Larmarque *et al.* (2010).

¹⁴¹ UNEP (2011).

¹⁴² *Ibid.*

¹⁴³ *Ibid.*

¹⁴⁴ UNEP (2011).

¹⁴⁵ Garg *et al.* (2006).

¹⁴⁶ UNEP (2011).

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inventory performed by the Indian Network for Climate Change Assessment (INCCA) that includes estimates for emissions of HFC-134a (from domestic and commercial refrigeration and air conditioning) and HFC-23 (emitted as a byproduct of HCFC-22 manufacturing).¹⁴⁷ IPCC default emission factors were used for the estimation of these HFC emissions.¹⁴⁸

The International Institute for Applied Systems Analysis (IIASA) developed the GHG-Air pollution Interactions and Synergies (GAINS) model as an extension to the Regional Air pollution Information and Simulation (RAINS) model. The GAINS 1.0 model considers emissions from activities that emit HFCs and divides these into 12 different sectors: HFC-23 production from HCFC-22 production; domestic refrigeration; commercial refrigeration, transport refrigeration; industrial refrigeration; stationary air conditioning; mobile air conditioning; aerosols; polyurethane one-component foam; other foams; and other HFC sources. One set of emission factors based on technology is applied globally. These emission factors account for the type of equipment (domestic refrigerator) and stage of life (use or disposal) but do not take into account characteristics such as the model or date of manufacture of the product.

The analysis performed in 2005 for the GAINS 1.0 model was updated in 2012 and includes all 11 LEAD countries with the exception of Papua New Guinea.¹⁴⁹ IIASA did not perform an uncertainty analysis but did identify that the uncertainties in the emission factors, particularly for mobile and stationary air conditioning, had an impact on the results.¹⁵⁰

Given that HFC emissions vary according to the type of technology, vintage of technology, hours of operation, and the frequency and quality of servicing, there will be a high level of uncertainty associated with HFC emission estimates from the GAINS model. The uncertainty for HFC use as foams, aerosols, and solvents is relatively low because all of the HFC gas used will likely be emitted over the course of the product's lifetime and/or at end-of-life. There is a much higher level of uncertainty associated with technologies such as chillers, stationary air conditioning, and mobile air conditioning, as the operation and servicing practices can vary greatly and thereby affect the emissions. Emissions from chillers or stationary air conditioning systems can be quite low if diligently serviced or they can be quite high if leaking systems are "topped off" rather than repaired. To develop accurate emission estimates, the conditions and use of technologies in each country should be taken into account.

5.2 Recommendations

Of the SLCPs, black carbon and HFCs are important climatic forcers. Black carbon is considered a greater forcing agent compared to tropospheric ozone; black carbon is more tractable and the emissions are easier to mitigate than emissions of ozone precursors; hence, reducing black carbon emissions would directly impact the region's climate and the global climate.¹⁵¹ For these two SLCPs, the areas of research that could bring the greatest benefit to LEAD countries include:

- For black carbon, two immediate areas of improvement of emission factors include development of black carbon emission factors for brick kilns and cook stoves. Although kilns and stoves account for a relatively small portion of emissions, there are many kilns and stoves in use

¹⁴⁷ Sharma *et al.* (2007).

¹⁴⁸ Sharma *et. al* (2011).

¹⁴⁹ Høglund-Isaksson (2013).

¹⁵⁰ Tohka (2005).

¹⁵¹ Larmarque (2013).

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across the entire region. Quantifying emissions from kilns and stoves and improving efficiency is relatively low-cost and more easily achievable than larger sources of emissions such as electricity generation. This would require substantial effort, however, given the diversity of technologies and fuels being used.

- For HFCs, developing regional emission factors of chillers, stationary air condition and mobile air conditioning would strengthen the HFC inventory for LEAD countries, although this would be challenging due to the variety of technologies in use and variation in servicing practices in use in each country.

Both of the efforts proposed above will likely require substantial research. In addition, for the effort of refining emission factors to be beneficial to the LEAD countries, additional efforts will likely be needed to also accurately portray the respective activity levels.

6. RECOMMENDATIONS AND PRIORITIZATION FOR EMISSION FACTOR IMPROVEMENT

The results from the research team's desk research and analysis (as indicated in the selection framework) and in-country consultations highlight the need for CSEFs in the Energy, Agriculture, and LULUCF sectors. While some source categories were identified for the Waste sector (i.e., CH₄ emissions from solid waste management) as well as Industrial Processes (i.e., IPPU CO₂ emissions from cement production), these were not emphasized as a relative priority across a large number of countries through in-country consultations. Based on the combination of results from the in-country consultations and the selection framework, the following categories are recommended for training and technical assistance to improve emission factors.

CH₄ Emissions from Rice Cultivation

This source category was mentioned in five in-country consultations, and also had among the highest scores of the selection framework. This is expected given that methane emissions from rice cultivation comprise significant shares of overall GHG emissions in national GHG inventories, and that approaches to rice cultivation (e.g., rainfed, irrigated, etc.) vary both within and among countries, with uncertainties present in the quantification for each of the approaches. Note that certain LEAD program countries (e.g., India, Vietnam) are already using Tier 2 methods to estimate CH₄ emissions from rice cultivation. Elements of these Tier 2 methodologies could potentially be transferred to countries currently using Tier 1 methodologies. A possible barrier to development of CSEFs for rice cultivation is the high cost of measurement equipment, the length of time required to implement the measuring system, and the personnel required to monitor such a system. Since similar rice management practices exist within the region, there might be opportunities for sharing emission factors among countries.

Land Use, Land-Use Change, and Forestry

Examples of applicable land use scenarios include changes in woody and forest biomass, conversion of forestland to grassland, and soil carbon. The specific LULUCF category(s) identified by each country depends on the country and its associated land use types. On aggregate, the study team's analysis of the selection framework led to this source category being among the priority categories (in seven out of 10 countries) and this category was mentioned as a priority in four in-country consultations. There were

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multiple sources related to the LULUCF sector that were identified as areas for emission factor development and improvement including changes in woody and forest biomass, conversion of forestland to grassland, and soil carbon factors. The emissions factors (which in some cases lead to sequestration rather than emissions) for these sources are highly dependent on country conditions, forest and other land use management practices, and land use types.

LULUCF sources in general are among the most significant sources of emissions in the region, as well as in some cases the most significant sources of sequestration, dominating the inventories in some countries and causing net emissions for the country as a whole to be either positive or negative with or without their inclusion. Furthermore, as there is considerable uncertainty in both the emissions factors and the activity data associated with LULUCF source categories. The development of training materials in this sector should take these country differences into account and consider approaches that would benefit both emissions factor development as well as activity data development in an integrated manner. One of the main challenges in improving estimates from this sector is classifying land use types in order to develop a more accurate estimate. Land cover maps are essential for this analysis, and are often unavailable due to budget and personnel resource constraints.

CH₄ Emissions from Enteric Fermentation

This source category was mentioned in four in-country consultations, and also had among the highest scores in the selection framework. Given the combination of very limited to no existing country-specific data on methane emissions from enteric fermentation, as well as the complexities and uncertainties in quantification of such emissions, we recommend this category as a priority for improvement. Note that some countries in the region e.g., India and Bangladesh are already using Tier 2 methods for enteric fermentation. Elements of these Tier 2 methodologies could potentially be transferred to countries currently using Tier 1 methodologies assuming animal characteristics and feeding patterns are similar between the countries.

CO₂ Emissions from Mobile Combustion

This source category was mentioned in five in-country consultations, and was among the top categories identified in the selection framework. Within the mobile combustion sector, quantifying CO₂ emissions from on-road transportation in an accurate and nationally representative manner was viewed a priority (while CH₄ and N₂O are also GHGs emitted from mobile combustion, they are much smaller in magnitude than CO₂ emissions in terms of CO_{2e}). The importance of improving emissions factors for this sector is underscored by the fact that the use of default emission factors does not fully take into account the diverse vehicle fleet that exists across LEAD partner countries including an array of new and efficient vehicles side by side with much older, inefficient vehicles as well as those that are undergoing transition from more to less carbon intensive fuels. Many data gaps within this source category are also related to activity data. This includes how transportation fuels are used, which types of vehicles are consuming these fuels, how much of each type is consumed, and where, are all important factors for future consideration.

CO₂ Emissions from Coal and Natural Gas Stationary Combustion

This source category was mentioned in four in-country consultations, and was among the top categories identified in the selection framework. A common issue in regard to usage of both of these fuels was the lack of composition data and the high degree of uncertainty associated with the quantities and composition of imported coal and natural gas. Further data on where these fuels were coming from, and

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their specific characteristics (including heating values and carbon contents) based on their country or region of origin would be needed to yield a more representative emissions factor for use nationally across many of the LEAD program countries.

The emission factor for this category could be estimates if fuel characteristics are known. There are also opportunities for determining the origin of coal and/or natural gas, and collecting appropriate activity data regarding where the coal and natural gas are imported from. If only a subset of countries is supplying fuel to the region, then the opportunity may exist to develop a factor relevant to multiple countries.

N₂O Emissions from Agricultural Soil Management

This source category was mentioned in three in-country consultations, and was among the top categories identified in the selection framework. This category cuts across a number of agricultural activities that have significant uncertainty embedded in the quantification of N₂O emissions, including land use conversion, fertilizer application for agricultural uses, waste management (including animal manure management) and peatlands/wetlands areas management.

As previously mentioned, there are two areas of SLCP research that could bring the greatest benefit to LEAD countries. These include:

- For black carbon, two immediate areas of improvement of emission factors include brick kilns and cook stoves. This would require substantial effort, however, given the diversity of technologies and fuels being used in each country.
- For HFCs, developing regional emission factors for HFC emissions from chillers, stationary air conditioning, and mobile air conditioning would strengthen the HFC inventory within each country though this would be challenging due to the variety of equipment technologies and servicing procedures applied in each country.

Both of the efforts proposed above will likely require substantial research and coordination with other organization's efforts in the region to quantify SLCP emissions (i.e., Climate and Clean Air Coalition).

7. NEXT STEPS FOR DETERMINING AN APPROACH FOR TRAINING AND TECHNICAL ASSISTANCE

Based on the results of the emission factor improvement analysis, the research team recommends six emission factors where the relevance and priorities for improvement vary by country. The approach for developing emission factors will also vary based on the availability of country-specific data. For example, a country with data already collected that can be used for developing a country-specific emission factor will have a different starting point than a country without any data available. In general, the following approach for training and technical assistance is recommended:

- 1) Define which emission factors should be targeted for training.
- 2) Determine overall applicability for each country to engage in training and technical assistance on emissions factor improvement.
- 3) Identify templates/training/standards already developed for specific emission factors.
- 4) Conduct research to determine data availability for each country to develop emission factors

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based on the recommended emission factor list.

- For those countries with readily available data:
 - Identify data gaps and work to resolve data gaps with a view to regional knowledge sharing by conducting online research to identify relevant organizations, consultations with national statistics organizations, etc.
 - For those countries that do not have readily available data:
 - Construct a plan to generate/collect necessary data
- 5) Determine the organization(s) that have the capabilities that are best suited to conduct emission factor training and development for the program. During this process, the study team should identify opportunities for coordination (e.g., with other USAID programs, other donors programs and national / sub-national development programs) that are already focusing on emissions factor improvement in order to maximize synergies, bring efficiencies and avoid duplication across similar efforts.
 - 6) Identify relevant national technical and policy experts that are both interested in obtaining training for emissions factor development and can apply the improved emission factors in their GHG management work in their countries.
 - 7) Determine most effective mode(s) of training and technical assistance. This would ideally entail regional training and knowledge-sharing events so that countries across the region could benefit from enhanced emissions factors that are common to them as well as offer the opportunity for more ‘advanced’ countries to share emission factor development knowledge with lesser advanced ones. The modes of training should be fully explored for pros and cons, but could entail for example the following approaches:
 - Regional training as part of a larger event (e.g., Asia LEDS Forum, National Communications workshops, WGIA meetings.);
 - Dedicated regional training that is stand-alone and focused exclusively on emission factor improvements; and/or
 - Targeted series of sub-regional trainings in countries with similar emission factor challenges.

The specific details of the approach for training will be further defined in future LEAD work (e.g., as part of the LEAD Fiscal Year 2014 work plan) in the region and will ultimately help countries develop more accurate national GHG inventory emission estimates from which to establish potential mitigation actions.

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Annex II: In-Country Consultations

The table below provides in-country consultations conducted to provide input on which emission factors are priorities for development in each country. The table outlines the country, the expert's name and their affiliation.

Table A-II 1: In-Country Expert Consultations

Country	Expert	Affiliation
Bangladesh	Prof. Syed Arwand Haque	Bangladesh Centre for Advanced Studies (BCAS)
	Dr. Ijaz Hossain	Bangladesh University of Engineering and Technology (BUET)
	A. M. Monsurul Alam	Department of Environment
	Sayeed Anware	Department of Environment
	Md. Yousuf Ali	Department of Environment
	Abdullah Al Mamun	Department of Environment
	S.M. Ahsan Ul Aziz	Department of Environment
	Md. Ziaul Haque	Department of Environment
	Dilruba Akten	Department of Environment
	QSI Hasmi	Department of Environment
	Mariam Akhter	FAO
	Sheikh Moazzem Hossain	Geological Survey of Bangladesh
	Mohammad Alauddin	Ministry of Power, Energy, and Mineral Resources
Cambodia	Uy Kamal	GHG Inventory & Mitigation Office at Ministry of Energy
India	Dr. N. H. Ravindranath	Indian Institute of Sciences (IISc)
	Dr. Himanshu Pathak, Dr. Niveta Singh, Dr. Arti Bhatia, Dr. Renu Singh	Indian Agriculture Research Institute (IARI)
	Dr. Sumana Bhattacharya	Independent GHG Inventory Consultant
	Dr. Anil Singh	Central Road Research Institute (CRRI)
	Dr. Chhemendra Sharma	National Physical Laboratory (NPL)
	Dr. Suman Majumdar	Confederation of Indian Industries (CII)
	Dr. R. Bhargava	Cement Manufacturer's Association (CMA)
	Dr. A. Choudhury	Central Institute for Mining and Fuel Research (CIMFR)
	<i>To be Scheduled</i>	The Energy Resources Institute (TERI)

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Indonesia	Bill Meade	Indonesia Clean Energy Development (ICED)
	Ami Dadiyanto	ICED
	Eli Nur Nirmala Sari	Indonesia Climate Change Centre (ICCC/DNPI)
	Artissa Panjaitan	Indonesia Climate Change Centre (ICCC/DNPI)
	Dadang Hilman	Indonesia Climate Change Centre (ICCC/DNPI)
	Emma Rachmawaty	Ministry of Environment (MoE)
	Augus Guanawan	Ministry of Environment (MoE)
	Prasetyadi Utomo	Ministry of Environment (MoE)
	Syamsidar Thamrin	BAPPENAS (Planning Ministry)
	Thomas Harvey	Indonesia National Carbon Accounting System (INCAS)
	Daniel Mudiyarso	Centre for International Forestry Research (CIFOR)
	Veronique De Sy	Centre for International Forestry Research (CIFOR)
	Arief Wijaya	Centre for International Forestry Research (CIFOR)
	Kristell Hergoualc'h	Centre for International Forestry Research (CIFOR)
	Shijo Joseph	Centre for International Forestry Research (CIFOR)
	Dr. Rizaldi Boer	Centre for Climate Risk and Opportunity Management in South East Asia and Pacific (CCROM)
Malaysia	Sazalina Zakaria	Malaysia Global Training Center
	Siti Raihana Abu Yazaid	Malaysia Global Training Center
Nepal	Dr. Balkrishna Sapkota	Solar Radiation and Aerosol in Himalaya Region (SAHR)
Philippines	Divina Chingcuanco	The Climate change and Clean energy Project (CEnergy)
	May Ajero	Clean Air Asia (CAI Asia)
	Alvin Mejia	Clean Air Asia (CAI Asia)
	Kaye Patdu	Clean Air Asia (CAI Asia)
	Joy Goco	The Climate Change Commission (CCC)
	Sandee Recabar	The Climate Change Commission (CCC)
	Florencia Pulhin	International Centre for Research and Agroforestry (ICFRAF)
	Dr. Rodel Lasco	International Centre for

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		Research and Agroforestry (ICFRAF)
	Dr. Leandro Buendia	EPA SEA II project
	Kaye Barriso	Department of Energy Planning and Policy Bureau
	Victoria Capito	Department of Energy Planning and Policy Bureau
	Albert Galang	DENR-Environmental Management Bureau (EMB)
	Arnel Manresa	Department of Transportation and Communications
	Bonar Laureto	Philippines Business for the Environment (PBE)
	Gene Alfred S. Morales	PIE, PricewaterhouseCoopers
	Maria Antonia Yulo-Loyzaga	The Manila Observatory
	Dr. James Simpás	The Manila Observatory
	Gemma Teresa T. Narisma	The Manila Observatory
Thailand	Dr. Vute Wangwacharakul	Center for Applied Economic Research, Kasetsart University
	Mr. Jassada Sakulku	Thailand Greenhouse Gas Management Organization
	Ms. Wasinee Wannasiri	Thailand Greenhouse Gas Management Organization
Vietnam	Nguyen Khac Hieu	Ministry of Natural Resources and Environment (MONRE)
	Quach Tat Quang	Ministry of Natural Resources and Environment (MONRE)
	Dr. Pham Manh Cuong	Ministry of Agriculture and Rural Development (MARD)
	Dr. Vu Tan Phuong	Ministry of Agriculture and Rural Development (MARD)
	Nguyen Mong Cuong	Research Center for Climate Change and Sustainable Development
	Bui Huy Phung	Viet Nam Academy of Science and Technology
	Hoang Van Tam	Ministry of Industry and Trade (MOIT)
	Nguyen Duc Cuong	Ministry of Industry and Trade (MOIT)
Other	Leandro Buendia	UNFCCC Southeast Asia Greenhouse Gas Inventory Capacity Building Project
	Dr. Stephen Ogle	NREL, Colorado State University
	Shuzo Nishioka	Institute for Global Environmental Strategies (IGES)

Annex III: Short-Lived Climate Pollutant Additional Information

Collection of SLCP Inventories and Information

Mitigation of pollutants considered in the UNFCCC national communication reports generally do not include mitigation of SLCPs.¹⁵² This demonstrates that conducting SLCP mitigation analysis is still in its infancy. Because of this, this analysis was informed by available SLCP inventories and literature reviews.

There are a number of inventories available that consider SLCP emissions in Southeast Asia. A few criteria were initially considered to benchmark the inventories that were identified during the research phase (see textbox *Considerations in Identifying Inventories*). Ultimately, one set of inventories was used to consider emission factors for black carbon and tropospheric ozone precursors and another set was used to explore emission factors for HFCs. During this process, it became evident that determining differences between inventories can be difficult, as the available inventory documentation generally does not provide details on the activity data and emission factors used.¹⁵³ Further, the uncertainty associated with emission factors and activity data has not been quantified for many inventories.¹⁵⁴

Considerations in Identifying Inventories

- Does it provide regional/country-specific emissions of SLCP?
- Does it provide emissions of SLCP by subcategory for each source category?
- Is the inventory transparent and provides appropriate citations for investigating the emission factors?
- Does the inventory description provide some level of uncertainty for each source category?
- Was the inventory recently developed?
- Has it been referenced in governmental reports?

For black carbon and tropospheric ozone precursors, this analysis draws primarily from the inventory produced through the NASA Intex-B study.¹⁵⁵ This inventory generally relies on emission factors used in the Transport and Chemical Evolution over the Pacific (TRACE-P) inventory,¹⁵⁶ except emission factors for vehicles is informed by the MOBILE model that takes into account emission standards. This inventory, specifically developed for Asia, informs two other Asian and global inventories: (1) Emissions for Atmospheric Chemistry and Climate Model Intercomparison Project (ACCMIP),¹⁵⁷ and (2) Regional Emission inventory in Asia (REAS) Version 1.1.¹⁵⁸ The global ACCMIP inventory was constructed to produce gridded SLCP emission data as input into the climate model simulations that support the IPCC Fifth Assessment report scheduled to be released in 2014.

¹⁵² India's second national communication was the only example where the mitigation of HFCs were considered. The NC2 included a number of ongoing or upcoming research projects to better understand SLCPs.

¹⁵³ Granier *et al.* (2011).

¹⁵⁴ Granier *et al.* (2011).

¹⁵⁵ Zhang *et al.* (2009). Data for all countries in the LEAD study area are provided except Papua New Guinea.

¹⁵⁶ Jacob *et al.* (2003).

¹⁵⁷ (Lamarque *et al.* 2010). For Southeast Asia, this inventory draws primarily from Regional Emission inventory in Asia (REAS) Version 1.1 which is informed by the NASA Intex-B study.

¹⁵⁸ Ohara *et al.* (2007).

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For HFCs, there was sparse inventory information available, as limited research has been conducted on this subject in this region. This analysis refers to the 2005 report by Antti Tohka about the GAINS Model for Greenhouse Gases as it provides details on the emission factors used for HFC technologies around the globe. Additional understanding of HFC emissions in the region was obtained through expert consultations (See Table A-III 1).

Expert Solicitation. Experts were contacted to discuss general considerations and recommendations for accurately portraying gaps and limitations in the emission factor source categories in Southeast Asia throughout this process. This provided ground-truthing of desk research results and clarification of specific pollutant/category concerns expressed in the literature.

Table A-III 1: List of Black Carbon, Tropospheric Ozone, and HFC Experts

Black Carbon	Tropospheric Ozone	HFCs
Dr. Jean-Francois Larmarque, National Center of Atmospheric Research	Dr. Jean-Francois Larmarque at National Center of Atmospheric Research	Bella Maranion, co-chair UNEP Technology and Economic Assessment Panel (TEAP)
Dr. Tami Bond, University of Illinois		Stephen Anderson, former co- chair UNEP Technology and Economic Assessment Panel (TEAP)

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Figures of SLCP Emissions in Southeast Asia

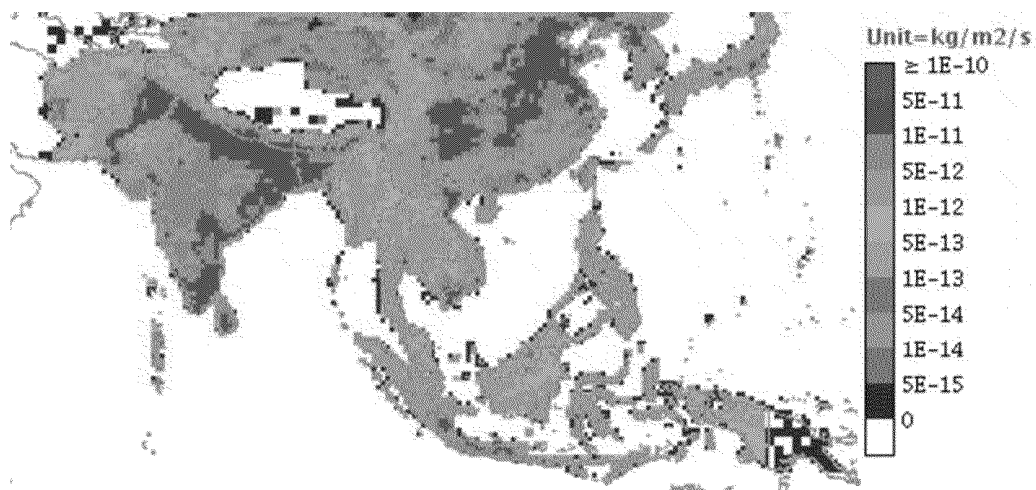


Figure A-III 1. Anthropogenic 2010 black carbon emissions in Asia. Source: REAS inventory, http://eccad.sedoo.fr/eccad_extract_interface/JSF/page_login.jsf.

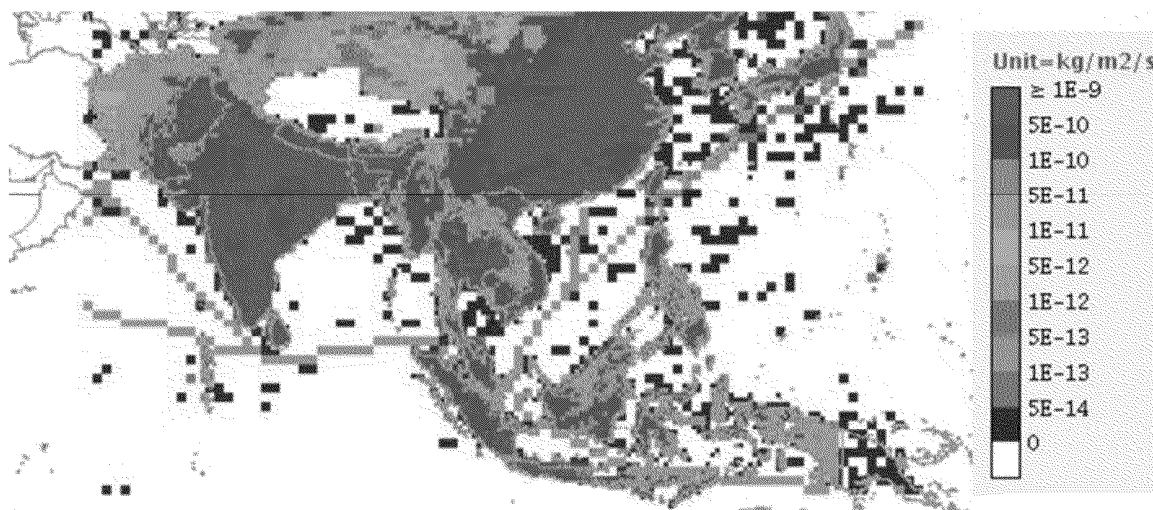


Figure A-III 2. Anthropogenic 2000 carbon monoxide emissions in Asia. Source: REAS inventory, http://eccad.sedoo.fr/eccad_extract_interface/JSF/page_login.jsf.

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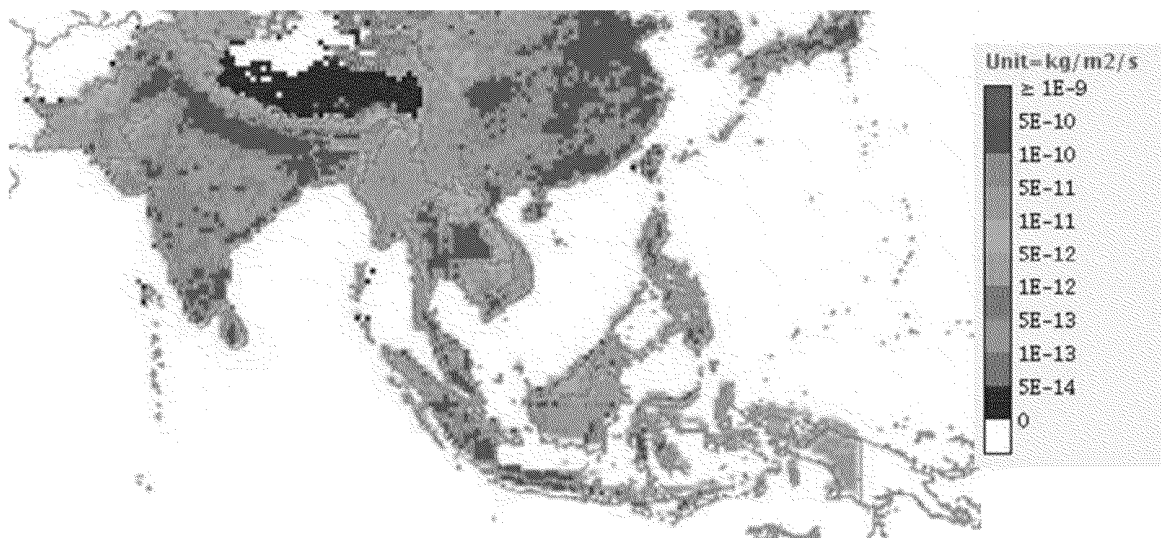


Figure A-III. 3. Anthropogenic 2000 non-methane volatile organic emissions in Asia. Source: REAS inventory, http://eccad.sedoo.fr/eccad_extract_interface/JSF/page_login.jsf.

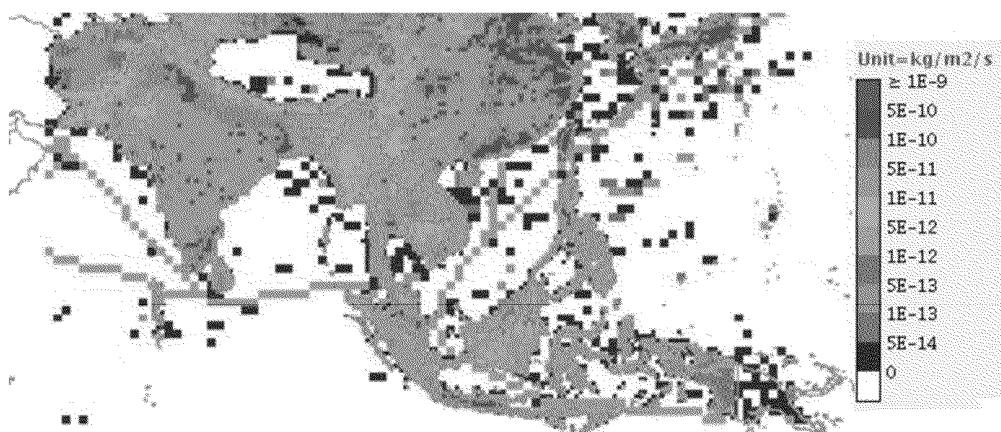


Figure A-III. 4. Anthropogenic 2000 nitrogen oxide emissions in Asia. Source: REAS inventory, http://eccad.sedoo.fr/eccad_extract_interface/JSF/page_login.jsf.



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Low Emissions Asian Development (LEAD) Program

Current Challenges and Priorities for Greenhouse Gas Emission Factor Improvement in Select Asian Countries

Agenda

- I. Overview of Methodology
 - I. National Communications
 - II. Expert Consultations
 - III. Key Category Analysis
 - IV. Emission Factor Framework
 - V. Short-Lived Climate Pollutants
- II. Country Results
- III. Recommendations
- IV. Questions/Discussion



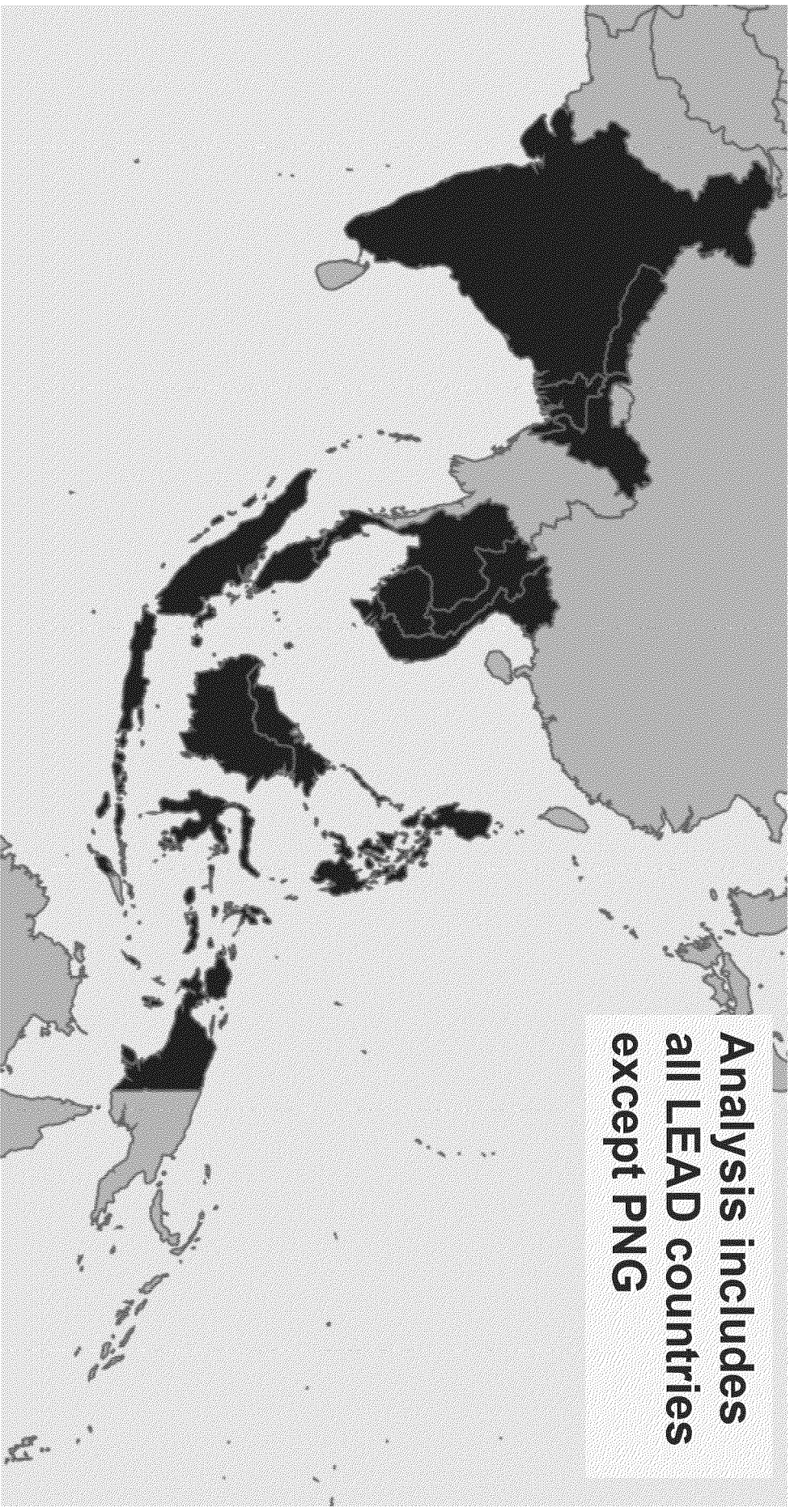
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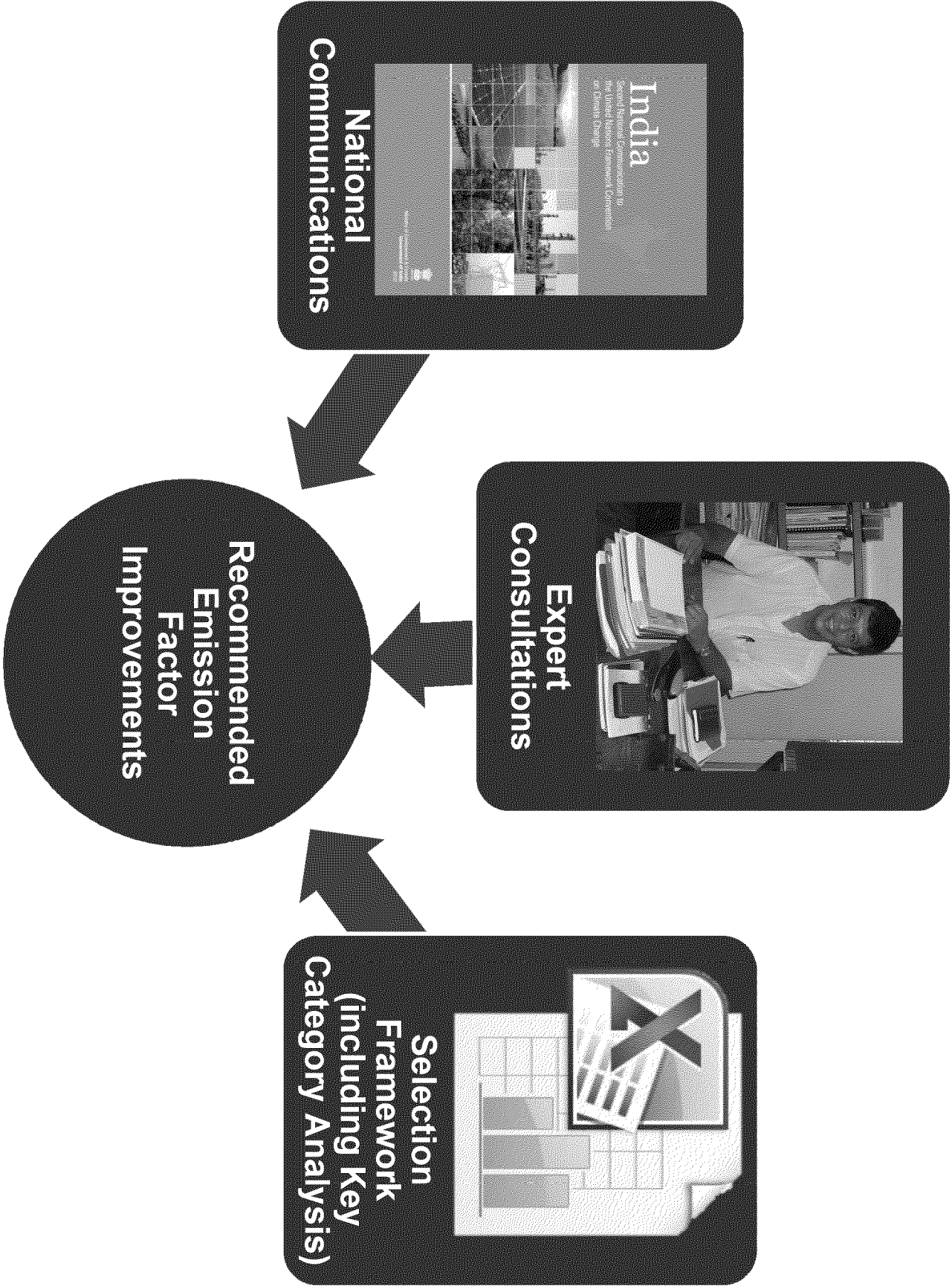
Overview of the Methodology



Countries Included in EF Assessment

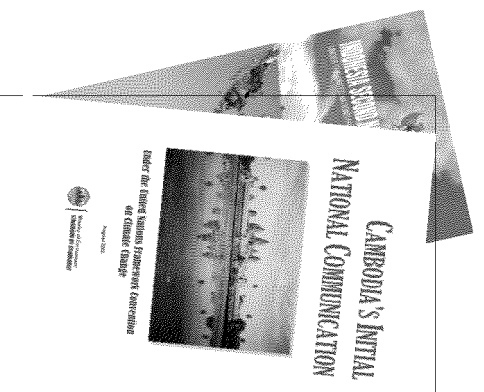


Developing Recommendations for EF Improvement



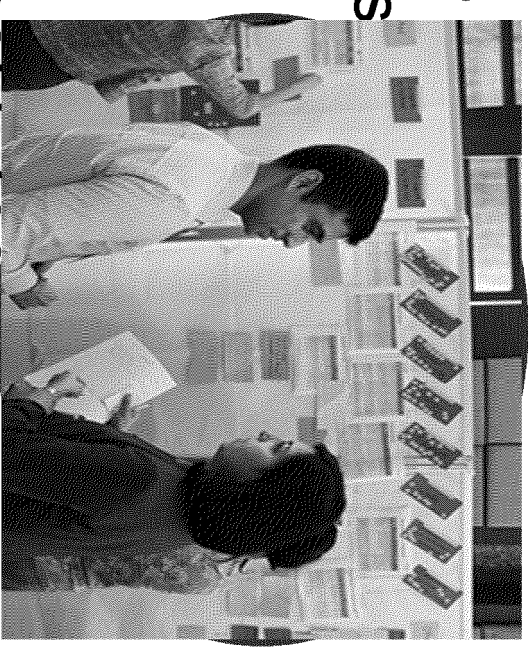
Review of National Communications

- Most recent NC reviewed for each country
- National Communications (NC) provide
 - ♦ GHG estimates and some context for estimates
 - ♦ Key category analyses (India, Malaysia, Indonesia)
 - ♦ Main ministries or experts involved
- Information may be out of date- some NCs for 1990 or 1994



Expert Consultations

1. Identified and contacted experts
 - ♦ Reviewed National Communications to identify key experts
 - ♦ Suggestions from USAID missions
 - ♦ Leveraged existing contacts
2. Contacted academic/research institutes
3. Conducted consultations
 - ♦ Current status of inventories, emission factors
 - ♦ Anticipated activities for improvement
 - ♦ Opportunities for capacity building
4. Discussions at LEDS-GP workshop



Insight from Expert Consultations

- Historical attempts to improve EFs
- Technical challenges
- Existing partnerships, support for inventory improvement
- Country-identified priorities for EF improvement
- Supplemental information on inventory uncertainties
- Regional synergies, shared EFs

Emission Factor Selection Framework

- Selection framework developed to conduct an objective evaluation of EFs used by countries
- Allows prioritization of certain EFs for further development
- Enabled the study team to:
 - ♦ determine relevant parameters of interest for which data was collected
 - ♦ allow comparisons among countries in a consistent and streamlined manner

Emission Factor Selection Framework

The main components of the framework are:

Key Category Analysis	Emission Factor Analysis
<ul style="list-style-type: none">• Indicate percentage share of sub-sector emissions to that of total sector (if available) and total national emissions• Provide context of relative importance to a sector, and which categories are “key”	<ul style="list-style-type: none">• List EFs used, whether the EF is a default (Tier 1) or country specific emission factor- CSEF (Tier 2)• Assess ease of deriving a CSEF• List any associated uncertainty• Provide a current status of EFs used in sectors/sub-sectors

Selection Framework Scoring System

Criteria		Scoring	
Percentage share of total national emissions	2	Source accounts for 0 to 5 percent of total national emissions	
	4	Source accounts for 5 to 10 percent of total national emissions	
	6	Source accounts for 10 to 15 percent of total national emissions	
	8	Source accounts for 15 to 20 percent of total national emissions	
	10	Source accounts for 20 to 25 percent of total national emissions	
	12	Source accounts for more than 25 percent of total national emissions	
Percentage share of sector emissions	1	Source accounts for up to 33 percent of a sector's total emissions	
	2	Source accounts for 33 to 66 percent of a sector's total emissions	
	3	Source accounts for 66 to 100 percent of a sector's total emissions	
Ease of emission factor development	1	Relatively Easy (e.g., stationary combustion)	
	2	Medium (e.g., industry (IPPU), mobile combustion, waste)	
	3	Complex (e.g., agriculture, LULUCF, fugitive emissions from oil and natural gas)	
Current tier and emission factors used	1	Tier 3, country-specific, local emission estimation methodology, or continuous emissions monitoring system (CEMS)	
	3	Tier 2, country-specific or mix of Tier 1 and Tier 2 emission factors	
		No information available in the NCs concerning tiers or estimation methods	
	5	Tier 1, default emission factors	
Level of uncertainty	1	Low	
	2	Medium	
	3	Unknown	
		High or similar to the IPCC Tier 1 emission factors	

Qualitative Considerations

Four key qualitative elements were reviewed for each country:

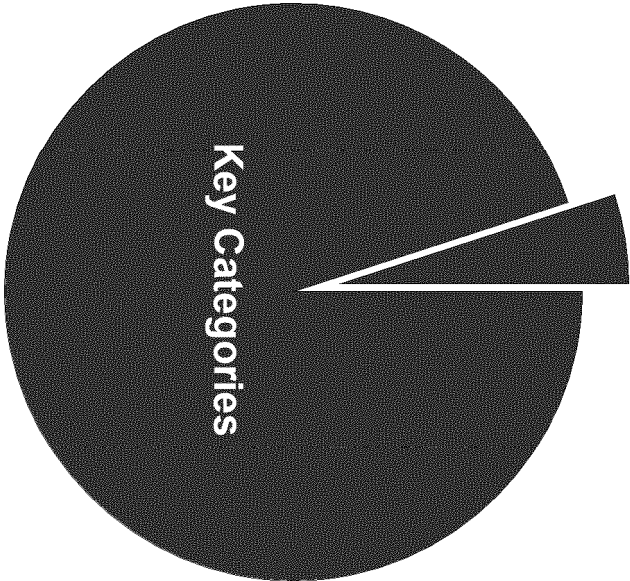
1. Potential of emission factor to be used by other countries with similar conditions
2. Relevance of emission factor to GHG mitigation programs/actions under consideration in LEAD countries
3. Studies already underway to improve the emission factor (i.e. by whom, status of efforts, future plans, etc.)
 - ♦ Domestic and internationally funded
4. Consideration of other existing or planned efforts to improve emission factor

Key Category Analysis (KCA)

IPCC Definition

“A category that is prioritized within the national inventory system because its estimate has a significant influence on a country’s total inventory of greenhouse gases in terms of the absolute level, the trend, or the uncertainty in emissions and removals. Refers to both source and sink categories.”

National Emissions



A KCA helps to identify where to focus efforts and resources for inventory and emission factor development

Key Category Analysis (KCA)

Three countries included key category analyses:

1. India

- Performed a KCA (excluding LULUCF)
- Included trend and level analyses

2. Malaysia

- Performed KCA with and without LULUCF
- Included level analysis only

3. Indonesia

- Performed a KCA with and without LULUCF
- Inconsistencies in reporting- independent KCA performed for EF analysis

Using the KCA Tool

ICF used GHG inventory information provided in the latest NC for each country to perform a KCA

Sector	Category			Input CO ₂ Equivalent Estimate Here		Base year (1990) absolute values
				Base year (1990)	Current year (2008)	
Energy	Fuel Combustion Activities - Energy Industries (Solid Fuel)	CO2	153,467	84,009	153,467	
		N2O	59,397	65,128	59,397	
		CH4	83,066	162,029	83,066	
		CO2	1,779	4,943	1,779	
		N2O	647	977	647	
		CH4	3,445	3,765	3,445	
		CO2	93,387	113,945	93,387	
		N2O	694	296	694	
		CH4	786	978	786	
		CO2	5,420	5,111	5,420	
		N2O	29	28	29	
		CH4	39	37	39	
		CO2	1,613	2,301	1,613	
		N2O	1	1	1	
		CH4	14	20	14	
		CO2	1,894	1,856	1,894	
		N2O	5	3	5	
CH4	131	104	131			
CO2	122	73	122			
N2O	3,341	2,258	3,341			
CH4	7,298	5,041	7,298			

Example: Energy Industries in Cambodia

Cambodia reports GHG emissions for “Energy Industries” while the KCA tool differentiates between solid, liquid, and gaseous fuels for Energy Industries

Cambodia’s GHG Inventory (NC1)

Sector and Source Categories
I. ENERGY
A. Fuel Combustion Activities
1. Energy industries
2. Manufacturing industries
3. Transport
4. Commercial/service
5. Residential
B. Biomass emissions*
SUB TOTAL (A+B)
CO₂ EQUIVALENT
TOTAL CO₂ EQUIVALENT

Sector	Category	Category Other/A
Energy		
1A1	Fuel Combustion Activities - Energy Industries (Solid Fuel)	
1A1	Fuel Combustion Activities - Energy Industries (Solid Fuel)	
1A1	Fuel Combustion Activities - Energy Industries (Solid Fuel)	
1A1	Fuel Combustion Activities - Energy Industries (Liquid Fuel)	
1A1	Fuel Combustion Activities - Energy Industries (Liquid Fuel)	
1A1	Fuel Combustion Activities - Energy Industries (Liquid Fuel)	
1A1	Fuel Combustion Activities - Energy Industries (Gaseous Fuel)	
1A1	Fuel Combustion Activities - Energy Industries (Gaseous Fuel)	
1A1	Fuel Combustion Activities - Energy Industries (Gaseous Fuel)	
1A1	Fuel Combustion Activities - Energy Industries (Gaseous Fuel)	
1A2	Fuel Combustion Activities - Manufacturing Industries and Construction	
1A2	Fuel Combustion Activities - Manufacturing Industries and Construction	
1A2	Fuel Combustion Activities - Manufacturing Industries and Construction	
1A3a	Fuel Combustion Activities - Transport - Domestic Civil Aviation	
1A3a	Fuel Combustion Activities - Transport - Domestic Civil Aviation	
1A3a	Fuel Combustion Activities - Transport - Domestic Civil Aviation	
1A3b	Fuel Combustion Activities - Transport - Road transportation	
1A3b	Fuel Combustion Activities - Transport - Road transportation	
1A3b	Fuel Combustion Activities - Transport - Road transportation	

Adjusting Emissions Values for the KCA Tool

Some GHG estimates were adjusted for the KCA tool based on available information

Adjustments made for Cambodia's GHG emission estimates in the KCA Tool

Sector Category		Gas
Energy	1A1 Fuel Combustion Activities - Energy Industries (Solid Fuel)	CO2
	1A1 Fuel Combustion Activities - Energy Industries (Solid Fuel)	N2O
	1A1 Fuel Combustion Activities - Energy Industries (Solid Fuel)	CH4
	1A1 Fuel Combustion Activities - Energy Industries (Liquid Fuel)	CO2
	1A1 Fuel Combustion Activities - Energy Industries (Liquid Fuel)	N2O
	1A1 Fuel Combustion Activities - Energy Industries (Liquid Fuel)	CH4
	1A1 Fuel Combustion Activities - Energy Industries (Gaseous Fuel)	CO2
	1A1 Fuel Combustion Activities - Energy Industries (Gaseous Fuel)	N2O
	1A1 Fuel Combustion Activities - Energy Industries (Gaseous Fuel)	CH4
	1A1 Fuel Combustion Activities - Energy Industries (Gaseous Fuel)	CO2
	1A2 Fuel Combustion Activities - Manufacturing Industries and Construction	N2O
	1A2 Fuel Combustion Activities - Manufacturing Industries and Construction	CH4
	1A3a Fuel Combustion Activities - Transport - Domestic Civil Aviation	CO2

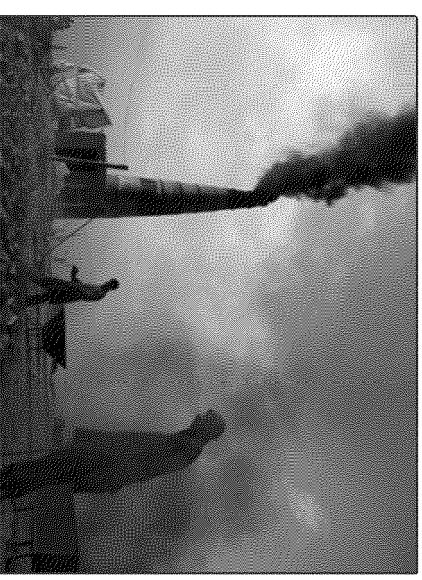
Derina Man:
Energy industries. Assume that 82% is solid (from biomass) and that 18% is petroleum (pg. 36, INC)

Derina Man:
Assume 18% petroleum sources (pg. 36, INC)

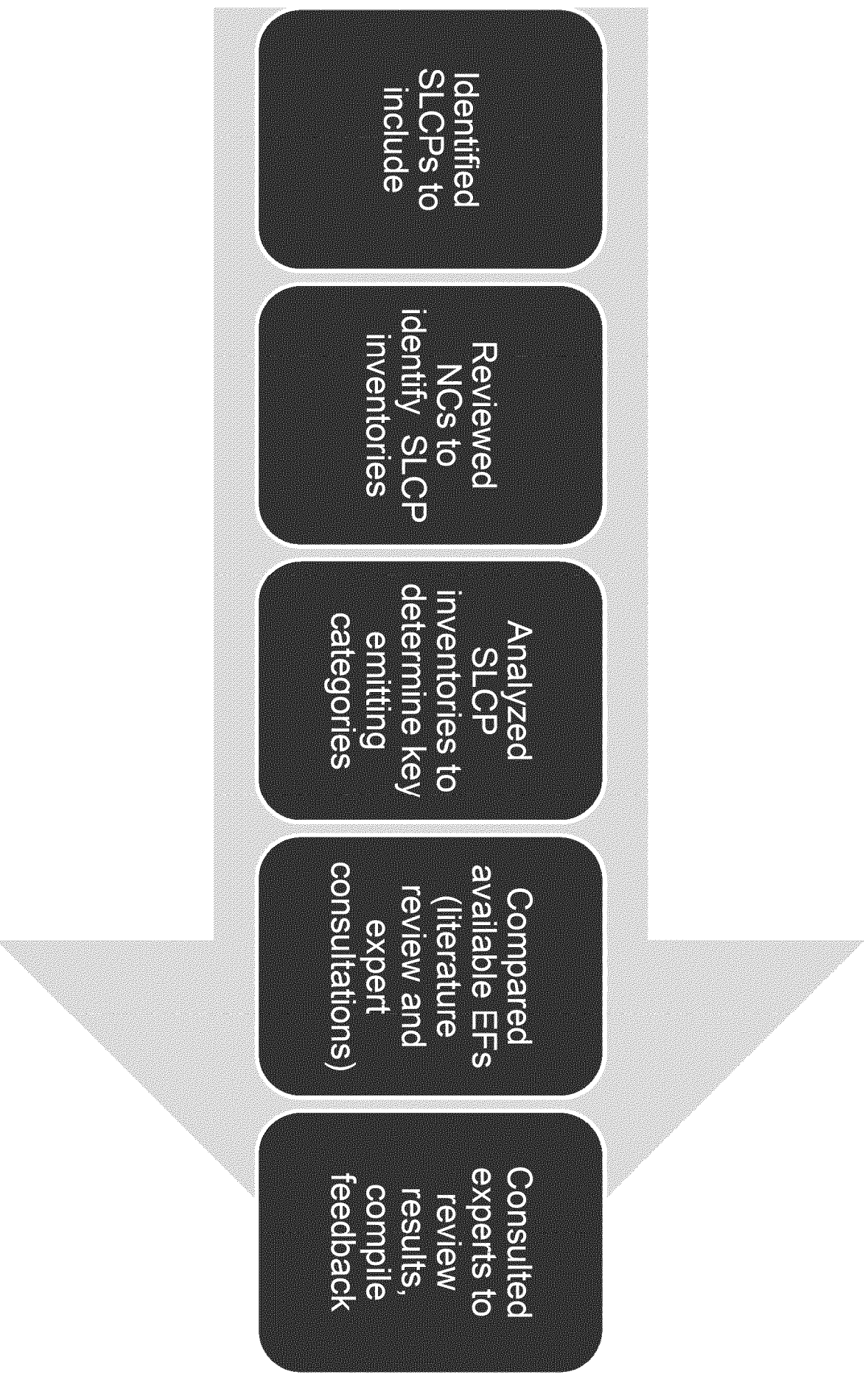
Short-Lived Climate Pollutants (SLCP)

Five SLCPs were considered for EF improvement:

1. Black carbon
2. Carbon Monoxide
3. Non-Methane Volatile Organic Compounds
4. Nitrogen Oxides
5. Hydrofluorocarbons

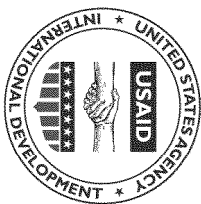


Approach to Understanding SLCP EFs



SLCP Experts

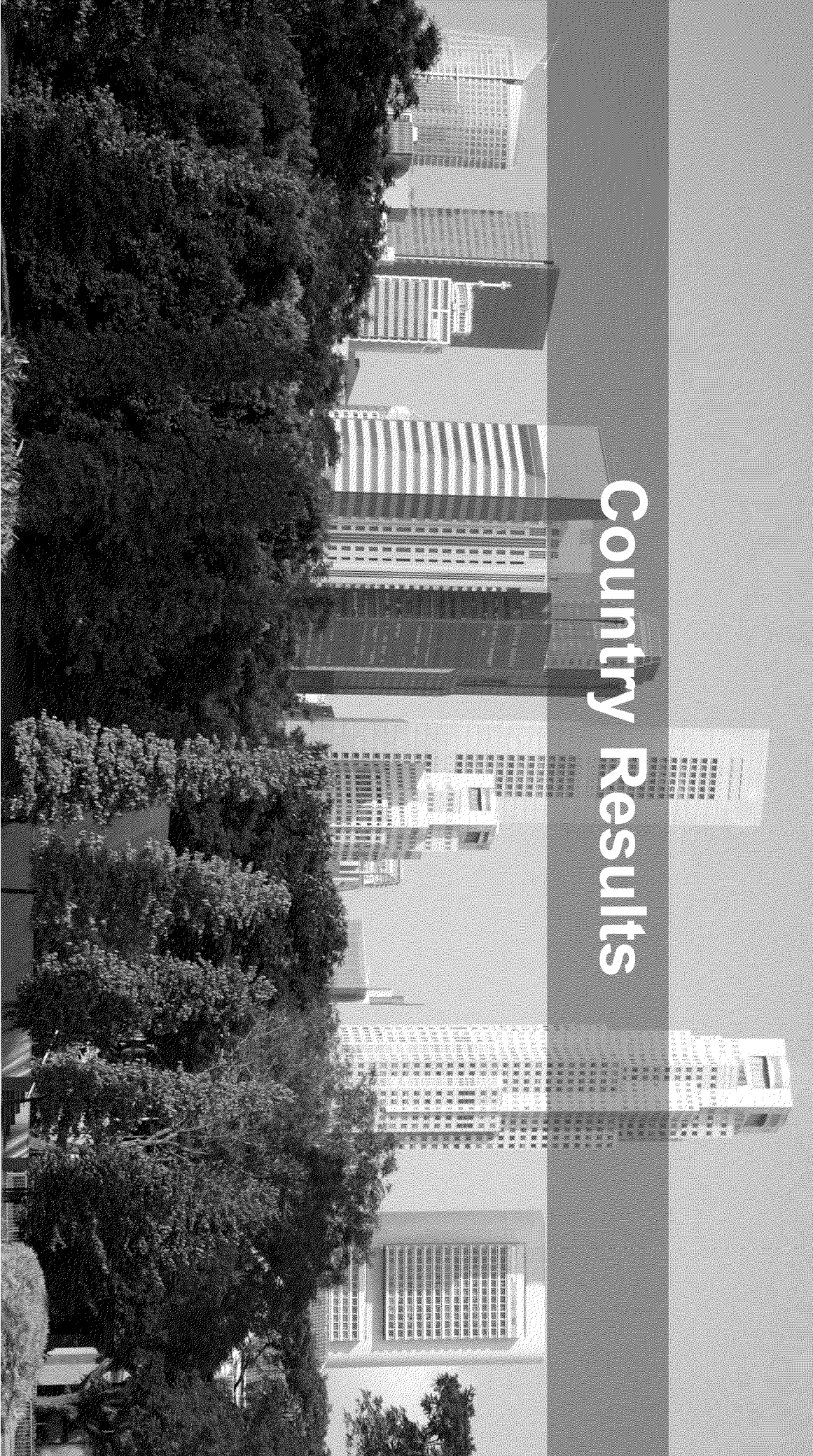
Black Carbon	Tropospheric Ozone	HFCs
Dr. Jean-Francois Larmarque, National Center of Atmospheric Research	Dr. Jean-Francois Larmarque, National Center of Atmospheric Research	Bella Maranion co-chair UNEP Technology and Economic Assessment Panel (TEAP)
Dr. Tami Bond, University of Illinois		Stephen Andersen, former co-chair UNEP Technology and Economic Assessment Panel (TEAP)



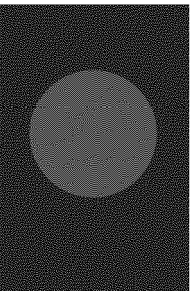
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Country Results



Bangladesh



Country Consultations

- Some Indian EFs applied (e.g., CH₄ from enteric fermentation)
- No EF improvement activities reported
- Department of Environment emphasized need for improved activity data
- Energy and agriculture sectors are priority areas

Current GHG Inventory Status

- NC2 for 2005
- Mostly IPCC default EFs
- Some expert judgment or regional EFs applied (not clearly defined)
- KCA based on NC2

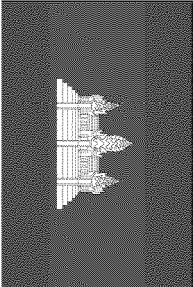
Priority Areas for Improvements

- **CO₂ emissions from imported coal (C, F)**
- **CO₂ emissions from stationary combustion (natural gas) (C, F)**
- CO₂ emissions from agricultural soils (C, F)
- CH₄ emissions from incineration and open burning of waste (F)
- **CH₄ emissions from enteric fermentation (C, F)**
- N₂O emissions from manure management (C, F)

C= Country identified

F= Identified in selection framework

Cambodia



Country Consultations

- Since NC1, Tier 2 EFs have been developed for acacia forests
- No planned activities to develop CSEFs
- Energy (stationary and mobile combustion) and agriculture (enteric fermentation and manure management) identified as priority areas

Current GHG Inventory Status

- NC1 for 1994
- All IPCC default EFs
- KCA based on NC1
- Six key categories identified in KCA, with top two from LULUCF
- LULUCF dominates GHG emissions (83 percent of total emissions)

Priority Areas for Improvements

- CO₂ emissions from stationary combustion (C)
- CO₂ emissions from mobile combustion (C)
- CO₂ removals from changes in forest and other woody biomass (F)
- CO₂ emissions from forest and land use change (F)
- CH₄ emissions enteric fermentation (C, F)
- Emissions from manure management (C)

C= Country identified

F= Identified in selection framework

India



Country Consultations

- Central Road Research Institute (CRRl) working on transport EFs
- Confederation of Indian Industries (CII) improving Tier 2 cement EFs, possibly Tier 3 methodologies
- Lack information on imported coal
- Identified LULUCF, IPPU, and mobile transport as priorities

Current GHG Inventory Status

- NC2 for 2000
- India Network for Climate Change Assessment produced national inventory for 2007
- Combination of IPCC EFs and CSEFs
- Performed own KCA on NC2
- Regional leader- opportunity to share EFs with other countries

Priority Areas for Improvements

- CO₂ emissions from electricity production (F)
- **CO₂ emissions from road transport (C, F)**
- CO₂ emissions from imported coal (C)
- **CH₄ emissions from rice cultivation (F)**
- CH₄ emissions from enteric fermentation (F)
- **N₂O emissions from agricultural soils (F)**

C= Country identified

F= Identified in selection framework

Indonesia

Country Consultations

- Efforts underway to develop CSEFs for agriculture
- Data collection activities underway to improve livestock data
- EFs for peatlands is a challenge
- Agriculture, peatlands, and changes in soil stock are priorities
- EFs for steel, iron need more specificity

Current GHG Inventory Status

- NC2 for 2000 to 2005
- Combination of IPCC and CSEFs
- Performed own KCA but there are inconsistencies; ICF performed separate KCA based on NC2
- 16 key categories identified; five categories are LULUCF
- LULUCF emissions calculated at provincial level

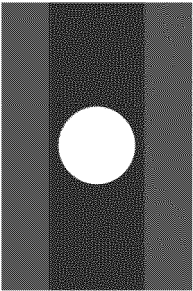
Priority Areas for Improvements

- **CO₂ emissions from forests converted to grasslands (F)**
- **CO₂ removals from forest and woody biostock (F)**
- CO₂ emissions from soils (C, F)
- CO₂ emissions from peat fires (C, F)
- **CH₄ emissions from enteric fermentation (C, F)**
- Emissions from manure Management (C)

C= Country identified

F= Identified in selection framework

Laos



Country Consultations

- Lack of capacity
- LEAD and LEAF conducting studies on LULUCF EFs
- Laos developing NAMAs, CSEFs would be helpful

Current GHG Inventory Status

- NC1 submitted for 1990
- All IPCC default EFs
- KCA based on NC1
- Some activity data is reliable (e.g., croplands) but many gaps exist

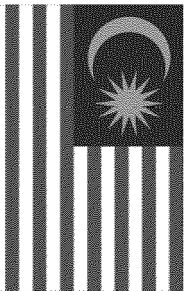
Priority Areas for Improvement

- **CO₂ emissions from forestland remaining forestland (C, F)**
- **CO₂ removals from forestland remaining forestland (C, F)**
- CO₂ emissions from aboveground decay (F)
- **CH₄ emissions from rice cultivation (C, F)**

C= Country identified

F= Identified in selection framework

Malaysia



Country Consultations

- Industries such as oil and natural gas production have emphasized the need for CSEFs based on GHG accounting methods adopted by industry
- No activities underway for CSEFs

Current GHG Inventory Status

- NC2 for 2000
- Mostly IPCC default EFs for NC1, NC2, and upcoming NC3
- Performed own KCA with and without LULUCF
- Energy is dominant sector in Malaysia's emissions

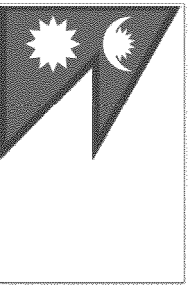
Priority Areas for Improvements

- CO₂ emissions from stationary combustion-energy (C, F)
- CO₂ emissions from mobile combustion (C, F)
- CO₂ emissions from forest and grassland conversion (F)
- CO₂ emissions from stationary combustion- manufacturing (C, F)
- CH₄ emissions from landfills (F)

C= Country identified

F= Identified in selection framework

Nepal



Country Consultations

- NC2 has been drafted
- No current efforts to develop CSEFs
- Some discussion on developing CSEFs for cook stoves
- In some cases, GHG emissions estimated using regional EFs
- LULUCF and Agriculture are priority areas

Current GHG Inventory Status

- NC1 for 1994
- Mostly IPCC default EFs
- KCA based on NC1
- 8 key categories; 5 from agriculture, 2 from LULUCF, and 1 from energy

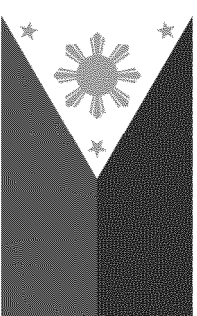
Priority Areas for Improvements

- CO₂ emissions from forest land converted to cropland (C, F)
- CO₂ removals from changes in woody and forest biomass (C, F)
- CO₂ from agricultural soils (C, F)
- CH₄ emissions from enteric fermentation (C, F)
- CH₄ emissions from rice cultivations (F)
- N₂O from agricultural soils (C, F)

C= Country identified

F= Identified in selection framework

Philippines



Country Consultations

- Starting work on NC3
- No current mandate to develop or improve EFs
- Transport, power, LULUCF sectors are high priorities
- Technical assistance and training from LEAD program needed for CSEF development
- Need for management systems

Current GHG Inventory Status

- NC1 for 1994, NC2 for 2000 (under review)
- Mostly IPCC default EFs
- KCA based on NC1
- 14 key categories identified
- Number of uncertainties related to LULUCF estimates
- Other sources, particularly those affected by population growth, ~~may now be priorities~~

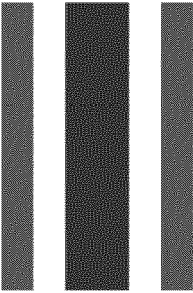
Priority Areas for Improvements

- CO₂ emissions and removals from forest and land use change (C, F)
- CO₂ emissions from biomass burning (C, F)
- CO₂ emissions from mobile combustion (C, F)
- CO₂ emissions from cement production (F)
- CO₂ emissions from iron and steel production (F)
- N₂O emissions from manure management (F)

C= Country identified

F= Identified in selection framework

Thailand



Country Consultations

- Currently developing NC3
- Focusing on transitioning to 2006 IPCC guidelines
- Developing EFs for fossil fuel combustion and waste water
- Energy, rice cultivation, enteric fermentation, manure management, and LULUCF are priorities

Current GHG Inventory Status

- NC2 for 2000
- Mostly IPCC default EFs
- CSEFs used GHGs from rice cultivation, forest management
- KCA based on NC2
- 13 key categories identified; half from energy
- EFs for LULUCF are not representative of forests

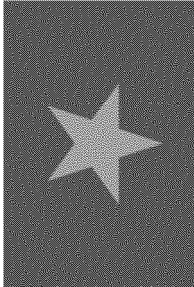
Priority Areas for Improvements

- **CO₂ emissions from stationary combustion-energy (C, F)**
- CO₂ emissions from cement production (C, F)
- **CO₂ emissions from mobile combustion (C, F)**
- **CO₂ emissions/removals from forest and grassland conversion (C, F)**
- **CH₄ emissions from enteric fermentation (C, F)**
- **CH₄ emissions from rice cultivation (C)**

C= Country identified

F= Identified in selection framework

Vietnam



Country Consultations

- JICA, through WGIA, is funding improvement of CSEFs
- Efforts undertaken to improve EFs for CH₄ from rice cultivation, CO₂ from coal combustion, fugitive CH₄ from coal mining
- IGES and MONRE developing CO₂ EF for national electricity system

Current GHG Inventory Status

- NC2 for 2000
- Mainly IPCC default EFs
- IPCC EFs and CSEFs used for CH₄ from rice cultivation
- KCA based on NC2
- 19 key categories identified

Priority Areas for Improvements

- CO₂ emissions from coal combustion (C)
- CO₂ removals from forest lands remaining forest lands (F)
- CO₂ emissions from forest soils (F)
- CH₄ emissions from rice cultivation (C, F)
- CH₄ emissions from enteric fermentation (C)
- Emissions from manure management (C)

C= Country identified

F= Identified in selection framework



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Recommendations



Highest Priority EFs Identified in Framework

	Rice Cultivation (CH ₄)	LULUCF (All)	Enteric Fermentation (CH ₄)	Stationary Combustion (CO ₂)	Mobile Combustion (CO ₂)	Agricultural Soils (N ₂ O)
Bangladesh		✓		✓		
Cambodia	✓	✓	✓			✓
India	✓				✓	✓
Indonesia		✓				
Laos	✓	✓				
Malaysia	✓	✓		✓	✓	
Nepal	✓	✓	✓			✓
Philippines		✓			✓	
Thailand		✓	✓	✓	✓	✓
Vietnam	✓	✓				

Recommendations for EF Improvement

Sector	Gas	Source
Agriculture	CH ₄	Rice Cultivation
LULUCF	CO ₂ , CH ₄ , N ₂ O	Country-dependent
Agriculture	CH ₄	Enteric Fermentation
Energy	CO ₂	Mobile Combustion
Energy	CO ₂	Coal and Natural Gas Stationary Combustion
Agriculture	N ₂ O	Agricultural Soil Management

Areas of SLCP sources recommended for additional research:

Gas	Source
Black Carbon	Brick Kilns and Cook Stoves
HFCs	Chillers, Stationary AC, Mobile AC

CH₄ from Rice Cultivation

Basis of recommendation

- Mentioned in 5 in-country consultations
- Among the highest scores of the selection framework

Challenges

- High cost of measurement equipment
- Time required to implement the measuring system and personnel required to monitor the system

Opportunities

- Regional emission factor sharing with countries using similar rice management practices

Land Use, Land-Use Change, and Forestry

Basis of recommendation

- Mentioned in 4 in-country consultations
 - Changes in woody and forest biomass, conversion of forestland to grassland, and soil carbon factors
- Among most significant sources in region

Challenges

- Dependent on country conditions, forest and other land use management practices, and land use types
- Land cover maps are essential and often unavailable (due to budget and personnel resource constraints)

Opportunities

- Improving EFs in this sector could significantly reduce the uncertainty of LEAD country GHG inventories

CH₄ from Enteric Fermentation

Basis of recommendation

- Mentioned in 4 in-country consultations
- Among the highest scores of the selection framework

Challenges

- Very limited to no existing country-specific data
- Complexities in quantification of emissions (due to very specific nature of animal characteristics and feeding practices)

Opportunities

- Regional emission factor sharing for countries with similar animal characteristics and feeding practices

CO₂ from Mobile Combustion

Basis of recommendation

- Mentioned in 5 in-country consultations
- Among the highest scores of the selection framework

Challenges

- Data gaps on how transportation fuels are used, which types of vehicles are consuming these fuels, how much of each type is consumed, and where

Opportunities

- Potential to group similar vehicle types among different countries

CO₂ from Stationary Combustion (Coal, Natural Gas)

Basis of recommendation

- Mentioned in 4 in-country consultations
- Among the highest scores of the selection framework

Challenges

- Lack of fuel composition data
- High uncertainty associated with the quantities and composition of imported coal and natural gas

Opportunities

- If only a subset of countries supply fuel to the region, then the opportunity may exist to develop a factor relevant to multiple countries

N₂O from Ag Soil Management

Basis of recommendation

- Mentioned in 3 in-country consultations
- Among the highest scores of the selection framework

Challenges

- Significant uncertainty in main emission sources
 - Land use conversion, fertilizer application for agricultural uses, animal manure management and peatlands/wetlands areas management

Opportunities

- Regional emission factor sharing for countries with similar management practices

Further SLCP EF Research Recommendations

Black Carbon

- Brick kilns, cook stoves
- High level of effort given the diversity of technologies and fuels being used

HFCs

- Chillers, stationary air conditioning, and mobile air conditioning
- Challenging due to the variety of equipment technologies and servicing procedures

Next Steps

- 1. Define emission factors for training**
- 2. Scoping exercise**
 - 1. Identify templates/training/standards already in place for EFs**
 - 2. Determine data availability and construct a plan based on countries with/without available data**
 - 3. Determine organizations to conduct the training**
 - 4. Identify technical and policy experts**
- 3. Determine most effective mode of training/technical assistance**

To: Ogle, Stephen[Stephen.Ogle@colostate.edu]; Wirth, Tom[Wirth.Tom@epa.gov]
Cc: ogle@nrel.colostate.edu[ogle@nrel.colostate.edu]; DelGrosso, Steve[Steve.DelGrosso@ARS.USDA.GOV]; Snow, Cassandra[Cassandra.Snow@icfi.com]; Flugge, Mark[Mark.Flugge@icfi.com]
From: Steele, Rachel
Sent: Fri 2/8/2013 4:20:03 PM
Subject: RE: FW: Sewage Sludge

Hi Stephen,

We will plan on sending the entire package to you and Steve D.G. the week of February 28th (Cassie Snow will send you the entire packet), if you need it before then please let us know.

Just so everyone is aware (I'm not trying to beat a dead horse here) this is the timeline we have to stick to for UNFCCC submissions. With that said, I recognize we are all working as quickly as we can to ensure accurate numbers are reported.

Sectoral Experts finalize Excel Bulk files for February 7 - 18	
Access team. Note: Summary.xls finalized	
January 31	
Database Team delivers 1990-2011 databases (XML) to SEs on rolling basis (CRF Reporter v. 3.6 database loaded with 1990-2011 data).	February 14-25
SE's complete SE Checklist-QAQC respective sectors in the Reporter, performing checks as specified by the Sectoral Expert checklist.	February 20 - March 5
SEs sector totals (and all subtotals) correct, March 5, 2013	
documentation complete and accurate [see SE checklist document]. Send XML to NIC	
Send sectoral CRF tables to EPA source leads for review.	March 5, 2013
EPA review.	March 5-14
NIC and SEs incorporate EPA comments.	March 12-18
Live database on NIC machine for final review; iteration with SEs to fill gaps, address data inconsistencies	March 19-31
Official submission transmitted by ICF to EPA (Leif Hockstad) for clearing with State and posting on UNFCCC portal.	April 1, 2013 (pending finalization of summary.xls)
Drop dead U.S. submission for posting on UNFCCC portal per UNFCCC reporting guidelines.	April 12, 2013

Best,

Rachel

RACHEL STEELE | Senior Associate | +1.202.862.1209 direct | Rachel.Steele@icfi.com | icfi.com

ICF INTERNATIONAL | 1725 Eye Street, NW Suite 1000, Washington, DC 20006 USA |

Connect with us on [social media](#)

From: Ogle,Stephen [mailto:Stephen.Ogle@colostate.edu]
Sent: Friday, February 08, 2013 11:06 AM
To: Steele, Rachel; Wirth.Tom@epamail.epa.gov
Cc: ogle@nrel.colostate.edu; DelGrosso, Steve; Snow, Cassandra; Flugge, Mark
Subject: RE: FW: Sewage Sludge

Rachel,

Our goal is to complete the new estimates by the first two weeks of March, and we just started the new simulations this week. At this point, I cannot state a specific date, and moreover, we want to make sure the estimates are final when we send them (not an almost final version). We know the pressure and deadlines, and you can be certain that we are working to send the estimates as soon as possible.

I don't think that it really matters about the timing of the spreadsheets. I copied the files into the our master directory this morning, but if you want me to remove them, I can do that as well, and then copy the files when you send them later.

Stephen Ogle

From: Steele, Rachel [<mailto:Rachel.Steele@icfi.com>]
Sent: Friday, February 08, 2013 8:58 AM
To: Ogle,Stephen; Wirth.Tom@epamail.epa.gov
Cc: ogle@nrel.colostate.edu; DelGrosso, Steve; Snow, Cassandra; Flugge, Mark
Subject: RE: FW: Sewage Sludge

Hi Stephen,

If it would make it easier for you, we can hold on to these spreadsheets and the chapter texts and then send them to you as a complete packet when you are ready? Maybe the week of February 25th?

As I'm sure you are aware, we are under pressure to get our UNFCCC submissions in through the CRF reporter and need finalized Ag Soils and LUC numbers as they impact other sectors (namely LULUCF). The inventory compilers here are anxious to get a finalized version. I'm hoping you could get us something by the week of March 4th?

Let me know what you think, we are happy to help in any way we can but also have a number of hard deadlines to meet.

Best,

Rachel

From: Ogle,Stephen [<mailto:Stephen.Ogle@colostate.edu>]
Sent: Friday, February 08, 2013 10:46 AM
To: Steele, Rachel; Wirth.Tom@epamail.epa.gov
Cc: ogle@nrel.colostate.edu; DelGrosso, Steve; Snow, Cassandra; Flugge, Mark
Subject: RE: FW: Sewage Sludge

Rachel,

We are just starting the new DAYCENT simulations, and this will take the rest of February. Our goal is to have the worksheets and text updated by the second week of March.

Stephen Ogle

From: Steele, Rachel [<mailto:Rachel.Steele@icfi.com>]
Sent: Friday, February 08, 2013 8:14 AM
To: Ogle,Stephen; Wirth.Tom@epamail.epa.gov
Cc: ogle@nrel.colostate.edu; DelGrosso, Steve; Snow, Cassandra; Flugge, Mark
Subject: RE: FW: Sewage Sludge

Hi Stephen and Steve,

Here are the live version of the Ag Soils and LUCFSoils files that went out for "Public Review". I am passing version control back to you. We have updated the Ag Soils file to include the 2011 sewage sludge data. Please use these file to update the DAYCENT time series and make any other changes.

Please let me know your estimated timeframe for delivering the final versions of these spreadsheets. We're beginning the process now to prepare the UNFCCC submission, so the sooner we have final numbers, the better.

Thanks and please let me know if you run into any issues or have concerns,

Best regards,

Rachel

From: Steele, Rachel
Sent: Monday, February 04, 2013 5:58 PM
To: Ogle,Stephen; Wirth.Tom@epamail.epa.gov
Cc: ogle@nrel.colostate.edu; DelGrosso, Steve; Snow, Cassandra
Subject: RE: FW: Sewage Sludge

Hi Stephen,

The inventory team here just noticed a few more anomalies with the Ag Soils spreadsheet that will need to be sorted out once the version comes back from Peer Review.

More specifically, it seems that the summary data found in **6-15 N₂O Emissions from Agriculture soils** is not matching the more detailed tables in the text below (e.g. **6-17 Direct N₂O Emissions from Agricultural Soils by Land Use Type and N Input Type**.) I've highlighted in red those numbers that aren't matching.

The values in the text match the values in the spreadsheet so it must be a formula error somewhere in the spreadsheet itself. The same is true for indirect, the summary table shows a total of 58.1 while the dis-aggregated Indirect N₂O Emissions from all Land-Use Types is showing 58.4 as the total. Finally I included the uncertainty table, the values there are not matching the other values in the tables, though it matches what is in the spreadsheet.

I realize you are traveling right now, and we have decided to go ahead with the text as is, I just wanted make you aware of the issue for when you have version control again.

Best regards,

Rachel

Table 6□15: N₂O Emissions from Agricultural Soils (Tg CO₂ Eq.)

Activity	1990	2005	2007	2008	2009	2010	2011
Direct	192.8	207.0	216.2	211.6	208.5	210.0	208.4
Cropland	119.5	135.5	142.9	138.9	136.2	138.0	137.8
Grassland	73.4	71.5	73.3	72.8	72.4	72.0	70.6
Indirect (All Land-Use Types)	52.4	46.4	60.9	59.2	57.9	58.7	58.1
Cropland	40.2	33.4	48.5		47.1	46.247.0	47.1
Grassland	11.9	12.2	11.6	11.3	11.0	10.9	10.4
Forest Land	+	0.1	0.1	0.1	0.1	0.1	0.1
Settlements	0.4	0.6	0.6	0.6	0.6	0.6	0.5

Total	245.3	253.3	277.0	270.8	266.4	268.7	266.5
	+ Less than 0.05 Tg CO ₂ Eq.						

Note: Quality control measures are still underway for Cropland and Grassland results, and estimates will be finalized after the public review.

Table 6□17: Direct N₂O Emissions from Agricultural Soils by Land Use Type and N Input Type (Tg CO₂ Eq.)

Activity	1990	2005	2007	2008	2009	2010	2011
Cropland	119.6	135.6	143.0	139.0	136.3	138.2	137.9
Mineral Soils	116.7	132.7	140.1	136.1	133.4	135.3	135.0
<i>Synthetic Fertilizer</i>	45.7	52.2	57.0	53.3	51.2	53.0	53.1
<i>Organic Amendment^b</i>	14.0	17.5	18.7	18.4	18.0	18.0	17.8
<i>Residue N^a</i>	4.9	5.1	5.0	5.1	5.0	5.1	4.8
<i>Mineralization and</i>							
<i>Asymbiotic Fixation</i>	52.0	58.0	59.4	59.3	59.1	59.3	59.3
Organic Soils	2.9	2.9	2.9	2.9	2.9	2.9	2.9
Grassland	73.4	71.5	73.3	72.8	72.4	72.1	70.9
Synthetic Fertilizer	2.3	2.5	2.5	2.5	2.5	2.5	2.5
PRP Manure	26.9	25.6	23.9	23.4	23.1	22.8	22.1
Managed Manure	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Sewage Sludge	0.3	0.5	0.5	0.5	0.5	0.5	+
Residue N ^c	2.4	2.7	2.8	2.8	2.8	2.8	2.8
Mineralization and							
Asymbiotic Fixation	41.3	40.1	43.4	43.4	43.3	43.3	43.3
Total	192.9	207.1	216.3	211.7	208.6	210.3	208.8

Table 6□19: Quantitative Uncertainty Estimates of N₂O Emissions from Agricultural Soil Management in 2011 (Tg CO₂ Eq. and Percent)

Source	Gas	2011 Emission Estimate (Tg CO ₂ Eq.)	Uncertainty Range Relative to Emission Estimate		
			(Tg CO ₂ Eq.)		(%)
			Lower Bound	Upper Bound	Lower Bound
Direct Soil N ₂ O Emissions	N ₂ O	209.1	132.6	364.2	-37%
Indirect Soil N ₂ O Emissions	N ₂ O	58.4	28.1	146.1	-52%

Note: Due to lack of data, uncertainties in managed manure N production, PRP manure N production, other organic fertilizer amendments, indirect losses of N in the simulations, and sewage sludge amendments to soils are currently treated as certain; these sources of uncertainty will be included in future Inventories.

Note: Quality control measures are still underway, and estimates will be finalized after the public review.

Methodological recalculations were applied to the entire time series to ensure time-series consistency from 1990 through 2011. Details on the emission trends through time are described in more detail in the Methodology section, above.

From: Ogle,Stephen [<mailto:Stephen.Ogle@colostate.edu>]
Sent: Thursday, January 24, 2013 10:01 PM
To: Wirth.Tom@epamail.epa.gov
Cc: ogle@nrel.colostate.edu; Steele, Rachel; DelGrosso, Steve
Subject: RE: FW: Sewage Sludge

OK, I will work with Steve to update the worksheets returned by ICF.

Cheers,

Stephen Ogle

From: Wirth.Tom@epamail.epa.gov [<mailto:Wirth.Tom@epamail.epa.gov>]
Sent: Thursday, January 24, 2013 6:29 AM
To: Ogle,Stephen
Cc: ogle@nrel.colostate.edu; Steele, Rachel; DelGrosso, Steve
Subject: RE: FW: Sewage Sludge

My only concern with that is that the inventory compilers at ICF may make some tweaks to the spreadsheet while they control it during the run-up to Public Review and so if Steve moves forward with changes to the version currently residing at CSU we may have problems later on. I think the sewage sludge issue is a fairly minor update, the main issue to me is that we don't let it slip through the cracks as it did on both the expert and public review phases.

Tom Wirth

US EPA -- Climate Change Division
Ph. (202) 343-9313
Fax. (202) 343-2359

Email: wirth.tom@epa.gov

▼ "Ogle,Stephen" ---01/23/2013 06:09:39 PM---Tom, This is my recommendation. However, I thought that Steve could go ahead and do the update with

From: "Ogle,Stephen" <Stephen.Ogle@colostate.edu>
To: Tom Wirth/DC/USEPA/US@EPA, "Steele, Rachel" <Rachel.Steele@icfi.com>
Cc: "ogle@nrel.colostate.edu" <ogle@nrel.colostate.edu>, "DelGrosso, Steve" <Steve.DelGrosso@ARS.USDA.GOV>
Date: 01/23/2013 06:09 PM
Subject: RE: FW: Sewage Sludge

Tom,

This is my recommendation. However, I thought that Steve could go ahead and do the update with a local version at CSU, and then we make the other updates after completing the re-run of DAYCENT (i.e., we would not deliver a new worksheet right now but after all changes had been made).

Stephen Ogle

From: Wirth.Tom@epamail.epa.gov [<mailto:Wirth.Tom@epamail.epa.gov>]
Sent: Wednesday, January 23, 2013 7:45 AM
To: Steele, Rachel
Cc: ogle@nrel.colostate.edu; DelGrosso, Steve
Subject: Re: FW: Sewage Sludge

Would it be better to wait and update the spreadsheet with the new sludge data until we get it back during public review. Better for version control.

Tom Wirth

US EPA -- Climate Change Division
Ph. (202) 343-9313
Fax. (202) 343-2359

Email: wirth.tom@epa.gov

▼ "Steele, Rachel" ---01/23/2013 09:40:19 AM---FYI From: Ogle,Stephen
[<mailto:Stephen.Ogle@colostate.edu>]

From: "Steele, Rachel" <Rachel.Steele@icfi.com>
To: Tom Wirth/DC/USEPA/US@EPA
Date: 01/23/2013 09:40 AM
Subject: FW: Sewage Sludge

FYI

From: Ogle,Stephen [<mailto:Stephen.Ogle@colostate.edu>]
Sent: Tuesday, January 22, 2013 7:22 PM
To: Steele, Rachel
Subject: RE: Sewage Sludge

Rachel,

Sure, send him an email so that he is in the loop.

Stephen Ogle

From: Steele, Rachel [<mailto:Rachel.Steele@icfi.com>]
Sent: Tuesday, January 22, 2013 5:17 PM
To: Ogle,Stephen; DelGrosso, Steve
Subject: RE: Sewage Sludge

Sounds good, do you want to let Tom know?

Thanks to you both,
Rachel

From: Ogle,Stephen [<mailto:Stephen.Ogle@colostate.edu>]
Sent: Tuesday, January 22, 2013 7:16 PM
To: Steele, Rachel; DelGrosso, Steve
Subject: RE: Sewage Sludge

Rachel,

OK, why don't we update this after public review. We definitely have to update the time series anyway.

Steve, can you go ahead and update the worksheets so this will be done.

Stephen Ogle

From: Steele, Rachel [<mailto:Rachel.Steele@icfi.com>]
Sent: Tuesday, January 22, 2013 5:13 PM
To: Ogle,Stephen; DelGrosso, Steve
Subject: RE: Sewage Sludge

The annex text is showing the same values for 2010 as 2011. The Ag Soils spreadsheet you sent to Tom does not seem to have the new sludge data included (i.e. it has "+"s) for 2011 sludge data, and the sludge tab is from August 2011 instead of October 2012.

From: Ogle,Stephen [<mailto:Stephen.Ogle@colostate.edu>]
Sent: Tuesday, January 22, 2013 7:10 PM
To: Steele, Rachel; DelGrosso, Steve
Subject: RE: Sewage Sludge

Rachel,

OK, so the spreadsheets are correct but the annex text is not correct? Or am I incorrect.

Stephen Ogle

From: Steele, Rachel [<mailto:Rachel.Steele@icfi.com>]
Sent: Tuesday, January 22, 2013 5:02 PM
To: DelGrosso, Steve
Cc: Ogle,Stephen

Subject: Sewage Sludge

Hi Steve,

I just wanted to make sure you had the most up to date sewage sludge info as it seems to be missing from the annex text.

Best regards,
Rachel

RACHEL STEELE | Senior Associate | +1.202.862.1209 direct | Rachel.Steele@icfi.com | icfi.com
ICF INTERNATIONAL | 1725 Eye Street, NW Suite 1000, Washington, DC 20006 USA |
Connect with us on [social media](#)

To: Wirth, Tom[Wirth.Tom@epa.gov]
Cc: Snow, Cassandra[Cassandra.Snow@icfi.com]; Ogle, Stephen
(Stephen.Ogle@colostate.edu)[Stephen.Ogle@colostate.edu]
From: Steele, Rachel
Sent: Sun 1/20/2013 1:25:49 PM
Subject: Updated Expert review Comments 1_20_2013
WAEES-JennerReviewofAgriculturalGHGEmissions011113 Ogle ICF.doc

Hi Tom,

Stephen sent me updated comments and I went through and reviewed with some additional edits.

Please let me know if you have any questions or concerns.

Best regards,

Rachel

RACHEL STEELE | Senior Associate | +1.202.862.1209 direct | Rachel.Steele@icfi.com | icfi.com

ICF INTERNATIONAL | 1725 Eye Street, NW Suite 1000, Washington, DC 20006 USA |

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To: Wirth, Tom[Wirth.Tom@epa.gov]
From: Ogle, Stephen
Sent: Wed 2/13/2013 7:24:18 AM
Subject: RE: Annexes and Figures for Draft Inventory of U.S. Greenhouse Gases and Sinks: 1990-2011 for Expert Review
[Snyder review EPA GHG 1990-2011 Inventory DRAFT 2012 tw Ogle.docx](#)

Tom,

I have attached responses to the comments that you requested, and a few others.

I agree with Cliff's comments on the lack of measurement data underlying the inventory. We have 50 experimental sites to infer how well the model is simulating the entire country. It has always seemed like a stretch to me, given the range of climate, soils and cropping systems that are not included in these experiments. With that being said, this approach is significantly better than the Tier 1 or 2 method (barring the problems we have had during the past year, of course).

This comment goes to the fundamental reason for implementation of the NRI soil monitoring network. It appears that USDA is about to end this program due to the recent funding cuts. However, this seems like a real disconnect between recent statements by the President on Climate Change, and moreover the push by the Secretary of Agriculture to establish reporting guidelines. I realize working in a different agency, this is probably not a major concern for you, but I would note that this network will do exactly what Cliff is suggesting for the national greenhouse gas inventory. Anyway, you may want to consider sending this comment as an FYI to the USDA Climate Change Program Office and possibly other contacts in USDA if appropriate. Ultimately this seems like an issue for USDA.

I will have to look at the new Clay et al paper, but we have worked on changing the max production of corn over time. Regardless this is why we do the reviews in my opinion, and we can do the additional testing requested for the corn yields. I will see if Keith's AFRI project can support this work. If not, you may want to consider this as planned improvement for this year (something we would work on in the early summer months).

Please confirm that you have received this email.

Cheers,

Stephen Ogle

From: Wirth.Tom@epamail.epa.gov [mailto:Wirth.Tom@epamail.epa.gov]
Sent: Monday, February 04, 2013 11:31 AM
To: ogle@nrel.colostate.edu
Subject: Fw: Annexes and Figures for Draft Inventory of U.S. Greenhouse Gases and Sinks: 1990-2011 for Expert Review

Steve,
We received some late comments on the Expert Review version of the inventory from Cliff Snyder at IPNI. I have provided preliminary responses for a number of them, but there are a few comments that I will need your input. I have also included the Expert Review version of the inventory that Cliff refers to in his comments

Please give me an idea for how long it will take for you to provide input on this so I can notify Leif.

Thanks,
Tom

(See attached file: Snyder review EPA GHG 1990-2011 Inventory DRAFT 2012_tw.docx)(See attached file: DRAFT US GHG Inventory 90-11-ER - Full Report.pdf)

Tom Wirth

US EPA -- Climate Change Division
Ph. (202) 343-9313
Fax. (202) 343-2359

Email: wirth.tom@epa.gov

----- Forwarded by Tom Wirth/DC/USEPA/US on 02/04/2013 01:23 PM -----

From: Cliff Snyder <csnyder@ipni.net>
To: GHGInventory@EPA
Cc: Leif Hockstad/DC/USEPA/US@EPA, Melissa Weitz/DC/USEPA/US@EPA, Tom Wirth/DC/USEPA/US@EPA
Date: 02/01/2013 07:59 PM
Subject: Re: Annexes and Figures for Draft Inventory of U.S. Greenhouse Gases and Sinks: 1990-2011 for Expert Review

Dear Leif and Melissa,

I regret that it was not possible to provide my invited review before now. Surgery, recuperation, personal leave, the holidays, travel, and the growing backlog of other work

commitments have taken a toll and delayed my response .

Attached below, please find my completed review of the 1990-2011 DRAFT Inventory report.

If you have any questions, please feel free to contact me.

Sincerely,

Clifford S. Snyder, PhD, CCA
Nitrogen Program Director
International Plant Nutrition Institute
P.O. Box 10509
Conway, AR 72034

Voice: 501-336-8110

Fax: 501-329-2318

Website: <http://www.ipni.net> [attachment "Snyder review EPA GHG 1990-2011 Inventory DRAFT 2012.docx" deleted by Tom Wirth/DC/USEPA/US]

To: Wirth, Tom[Wirth.Tom@epa.gov]
Cc: Aguiar, Amie[Amie.Aguiar@erg.com]
From: Cortney Itle
Sent: Mon 2/4/2013 7:40:43 PM
Subject: Re: Fw: Updated Expert review Comments 1_20_2013
[WAEES-JennerReviewofAgriculturalGHGEmissions011113_Ogle_ICF_ERG.docx](#)
[ATT32356.gif](#)

Tom,

Our responses are included in the attached. Please let me know if you would like to discuss any of them.

Thanks!
Cortney

Cortney Itle
Environmental Engineer
Eastern Research Group, Inc.
703-424-8360

>>> <Wirth.Tom@epamail.epa.gov> 2/4/2013 9:39 AM >>>

Thanks, that will be great.

Tom Wirth

US EPA -- Climate Change Division
Ph. (202) 343-9313
Fax. (202) 343-2359

Email: wirth.tom@epa.gov

▼ "Cortney Itle" ---02/04/2013 09:34:59 AM---Tom, My apologies! I was out of the office most of last week at a conference and overwhelmed on Frid

From: "Cortney Itle" <Cortney.Itle@erg.com>
To: Tom Wirth/DC/USEPA/US@EPA
Cc: "Amie Aguiar" <Amie.Aguiar@erg.com>
Date: 02/04/2013 09:34 AM
Subject: Re: Fw: Updated Expert review Comments 1_20_2013

Tom,

My apologies! I was out of the office most of last week at a conference and overwhelmed on Friday with an overflowing in box. I will send these today.

-Cortney

Cortney Itle
Environmental Engineer
Eastern Research Group, Inc.
(703) 424-8360

>>> 02/02/13 1:02 PM >>>

Cortney,
I really need your input on these commens ASAP.
thanks
tom

Tom Wirth

US EPA -- Climate Change Division
Ph. (202) 343-9313
Fax. (202) 343-2359

Email: wirth.tom@epa.gov

-----Tom Wirth/DC/USEPA/US wrote: -----

To: Cortney.Itle@erg.com, Amie Aguiar <Amie.Aguiar@erg.com>
From: Tom Wirth/DC/USEPA/US
Date: 01/22/2013 08:39AM
Subject: Fw: Updated Expert review Comments 1_20_2013

Cortney and Amie,
Find attached ICF/CSU responses to the comments from Mark Jenner that we received during the expert review. In the attached file there are some places for ERG to insert their input. Can you put your responses directly into this file so I have a consolidated file of comments and responses.

Please also remember that I need the manure spreadsheet today and the text files by Friday. Seems like there are some changes to the text files based on these Jenner comments.

Thanks
Tom

Tom Wirth

US EPA -- Climate Change Division
Ph. (202) 343-9313
Fax. (202) 343-2359

Email: wirth.tom@epa.gov

----- Forwarded by Tom Wirth/DC/USEPA/US on 01/22/2013 08:34 AM -----

From: "Steele, Rachel" <Rachel.Steele@icfi.com>
To: Tom Wirth/DC/USEPA/US@EPA
Cc: "Snow, Cassandra" <Cassandra.Snow@icfi.com>, "Ogle,Stephen (Stephen.Ogle@colostate.edu)" <Stephen.Ogle@colostate.edu>
Date: 01/20/2013 08:26 AM
Subject: Updated Expert review Comments 1_20_2013

Hi Tom,

Stephen sent me updated comments and I went through and reviewed with some additional edits.

Please let me know if you have any questions or concerns.

Best regards,
Rachel

RACHEL STEELE | Senior Associate | +1.202.862.1209 direct | Rachel.Steele@icfi.com | icfi.com
ICF INTERNATIONAL | 1725 Eye Street, NW Suite 1000, Washington, DC 20006 USA |
Connect with us on [social media](#)
(See attached file: WAEES-JennerReviewofAgriculturalGHGEmissions011113_Ogle_ICF.doc)

[attachment "WAEES-JennerReviewofAgriculturalGHGEmissions011113_Ogle_ICF.doc" removed by Tom Wirth/DC/USEPA/US]

To: Wirth, Tom[Wirth.Tom@epa.gov]
Cc: Creech, Jay[Jay.Creech@icfi.com]
From: Steele, Rachel
Sent: Wed 12/4/2013 6:33:35 PM
Subject: RE: Agricultural Soil Management Chapter
6 4 Agricultural Soil Management (IPCC Source Category 4D) 3Dec2013 JC.docx

Hi Tom!

Please see our responses, in short the first answer is yes and the second answer is no.

Hope this helps,

Best,

Rachel

RACHEL STEELE | Senior Associate | +1.202.862.1209 direct | Rachel.Steele@icfi.com | icfi.com

ICF INTERNATIONAL | 1725 Eye Street, NW Suite 1000, Washington, DC 20006 USA |

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From: Wirth, Tom [mailto:Wirth.Tom@epa.gov]
Sent: Wednesday, December 04, 2013 11:58 AM
To: Steele, Rachel
Subject: FW: Agricultural Soil Management Chapter

Rachel,

Can you confirm on Steve's questions about the sewage references. In two places he has comments.

Thanks

Tom

Tom Wirth

US Environmental Protection Agency

Climate Change Divison

Tel: 202 343-9313

Mobile: 703 399-1594

Wirth.tom@epa.gov

From: Ogle,Stephen [<mailto:Stephen.Ogle@colostate.edu>]

Sent: Tuesday, December 03, 2013 11:51 PM

To: Wirth, Tom

Subject: Agricultural Soil Management Chapter

Tom,

Here is the draft version of the soil management chapter for the NIR. Let me know if you have any questions. I plan to send the annex tomorrow.

Stephen Ogle

To: Mark Jenner[mjenner@waees-llc.com]; Wirth, Tom[Wirth.Tom@epa.gov]
From: Ogle,Stephen
Sent: Fri 6/21/2013 6:50:55 PM
Subject: RE: Clarification of terms in 2013 Soil Management GHG Emissions

Mark,

Ex. 5 - Deliberative Process

Let me know if you have additional questions.

Stephen Ogle

From: Mark Jenner [mailto:mjenner@waees-llc.com]
Sent: Wednesday, June 19, 2013 4:41 PM
To: Ogle,Stephen; 'Wirth, Tom'
Subject: RE: Clarification of terms in 2013 Soil Management GHG Emissions

Stephen (and Tom)

I have had a little more time to work on this project since my initial request last week so I will try to clarify.

Ex. 5 - Deliberative Process

Ex. 5 - Deliberative Process

Ex. 5 - Deliberative Process

Thanks for your note. I hope this helps clarify my initial note.

Peace!

Mark

Mark Jenner, PhD, WAEES

573.228.9007

www.waes-llc.com

‘Manure’ is not a four-letter word

From: Ogle, Stephen [mailto:Stephen.Ogle@colostate.edu]
Sent: Wednesday, June 19, 2013 4:21 PM
To: Wirth, Tom
Cc: mjenner@waees-llc.com
Subject: RE: Clarification of terms in 2013 Soil Management GHG Emissions

Tom (and Mark),

Ex. 5 - Deliberative Process

Ex. 5 - Deliberative Process

We could discuss other ways to present the data if it would improve transparency.

Cheers,

Stephen Ogle

From: Wirth, Tom [<mailto:Wirth.Tom@epa.gov>]
Sent: Tuesday, June 11, 2013 11:44 AM
To: Ogle, Stephen
Cc: mjenner@waees-llc.com
Subject: FW: Clarification of terms in 2013 Soil Management GHG Emissions

Steve,

Please take a look at the request below from Mark Jenner regarding some questions on the soil C/N₂O estimates. Mark has been doing a very thorough review of our GHG inventory starting with enteric and he has provided a lot of very useful insights into how we can improve our methods, data and NIR transparency. I am hopeful his review will be helpful in same way for these sources.

Please reply to Mark and cc me in your response so he has an idea of your ability to provide the information he is requesting—

Ex. 5 - Deliberative Process

Ex. 5 - Deliberative Process

Ex. 6 - Personal Privacy

Cheers,

Tom

Tom Wirth

US Environmental Protection Agency

Climate Change Division

Tel: 202 343-9313

Mobile: **Ex. 6 - Personal Privacy**

Wirth.tom@epa.gov

From: Mark Jenner [<mailto:mjenner@waees-llc.com>]

Sent: Monday, June 10, 2013 6:06 PM

To: Wirth, Tom

Subject: Clarification of terms in 2013 Soil Management GHG Emissions

Tom,

I have tried to honor your request for fewer emails, but am have run up against more barriers. The information that Katrin and you provided for my work on the livestock emissions was invaluable. I hope it helped identify useful information for your work. Thank you for making it possible for me to get that information.

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Ex. 5 - Deliberative Process

Thanks again for all your guidance.

Mark

Mark Jenner, PhD

Senior Environmental Economist

World Agricultural Economic and Environmental Services (WAEES)

3215 S. Providence Rd, Suite 4

Columbia, MO 65203

Email: mjenner@waees-llc.com

Office Phone: 573-228-9007

Fax: 573-228-9799

Cell Phone: **Ex. 6 - Personal Privacy**

Website: www.waees-llc.com

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virus which could cause harm to EPA's computers, network, and data. The
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If the message sender is known and the attachment was legitimate, you should
contact the sender and request that they rename the file name extension and
resend the Email with the renamed attachment. After receiving the revised
Email, containing the renamed attachment, you can rename the file extension to
its correct name. For further information, please contact the EPA Call Center
at (866) 411-4EPA (4372). The TDD number is (866) 489-4900.

***** ATTACHMENT NOT DELIVERED *****

To: Wirth, Tom[Wirth.Tom@epa.gov]
From: Ogle,Stephen
Sent: Sat 12/7/2013 7:29:19 PM
Subject: RE: Annex
[Annex 3 12 Methodology for Estimating N2O Emissions and Soil Organic C Stock Changes_6Dec2013_clean.docx](#)
[Annex 3 12 Methodology for Estimating N2O Emissions and Soil Organic C Stock Changes_6Dec2013_tracked changes.docx](#)
[7.2 Forest Land Remaining Forest Land \(IPCC Source Category 5A1\) - Soil N2O_6December2013_clean.docx](#)
[7.9 Settlements Remaining Settlements. - N2O Fluxes from Soils 6December2013_clean.docx](#)

Tom,

Here is the annex again with a few more adjustments. I have also attached the settlements and forestland, although you should already have these files.

Stephen Ogle

From: Wirth, Tom [mailto:Wirth.Tom@epa.gov]
Sent: Saturday, December 07, 2013 8:05 AM
To: Ogle,Stephen
Cc: Wirth, Tom
Subject: RE: Annex

Steve,

Ex. 5 - Deliberative Process

Ex. 5 - Deliberative Process

Tom

From: Ogle, Stephen <Stephen.Ogle@colostate.edu>
Sent: Friday, December 06, 2013 8:58 PM
To: Wirth, Tom
Subject: Annex

Tom,

Here is the annex in both track changes and a “clean version”. References to other chapters and annexes are highlighted in yellow in the “clean version” so that ICF can check the numbers in case they have changed.

Stephen Ogle

To: Nalin Srivastava[srivastava@iges.or.jp]; Wirth, Tom[Wirth.Tom@epa.gov]
Cc: 'Kiyoto TANABE'[tanabe@iges.or.jp]; 'NGGIP-TSU'[nggip-tsu@iges.or.jp]; Delgado, Jorge[Jorge.Delgado@ARS.USDA.GOV]
From: Delgado, Jorge
Sent: Fri 11/1/2013 4:06:00 AM
Subject: RE: IPCC - I respectfully submit the following argument for changing two of the factors to assess the N2O emissions from crop residue.
[15N Cover Crops Potatoes Collins Delgado Alva Follett.pdf](#)
[15N Crop Residue IPCC Methodologies Delgado DelGrosso Ogle 2010.pdf](#)
[Data form 20120214 Crop Residue with High C N Ratio Delgado October 31 2013.xls](#)
[Data form 20120214 Nitrate Leaching Coefficient October 31 2013.xls](#)
[Delgado et al 2004 Crop Residue 15N.pdf](#)
[Delgado Recommendations IPCC October 31 2013.docx](#)
[Jackson 2000.pdf](#)
[Toma Hatano 2007.pdf](#)

Dear Nalin and all

Attached is the requested data (2 Excel files)

I attached all the supportive material (peer review papers and edited-updated (minor edits) cover letter).

Looking forward to your response/comments

Do not hesitate to contact me if you need additional information

I will be traveling next week and the week of the 18-22 November but will be checking my email

Jorge

From: Nalin Srivastava [mailto:srivastava@iges.or.jp]
Sent: Wednesday, October 23, 2013 12:51 AM
To: Delgado, Jorge; 'Wirth, Tom'
Cc: 'Kiyoto TANABE'; 'NGGIP-TSU'
Subject: RE: IPCC - I respectfully submit the following argument for changing two of the factors to assess the N2O emissions from crop residue.

Dear Jorge,

Thank you so much for submitting data on soil N2O for the EFDB. It is fine to submit the data forms by October 29th.

Please don't hesitate to let me know if you need any help.

Best,

Nalin

From: Delgado, Jorge [mailto:Jorge.Delgado@ARS.USDA.GOV]
Sent: 23 October 2013 14:56
To: Nalin Srivastava; 'Wirth, Tom'
Cc: 'Kiyoto TANABE'; 'NGGIP-TSU'; Delgado, Jorge
Subject: RE: IPCC - I respectfully submit the following argument for changing two of the factors to assess the N2O emissions from crop residue.

Hi to all.

I am in Baja California, Mexicali Mexico at an International Meeting invited to conduct a Nitrogen Index workshop and a key note opening presentation.

I will be back to the USA this weekend. I will try to email you the requested information Monday October 28th or Tuesday October 29th at the latest.

Jorge

From: Nalin Srivastava [<mailto:srivastava@iges.or.jp>]
Sent: Tuesday, October 22, 2013 7:35 AM
To: 'Wirth, Tom'
Cc: 'Kiyoto TANABE'; Delgado, Jorge; 'NGGIP-TSU'
Subject: RE: IPCC - I respectfully submit the following argument for changing two of the factors to assess the N2O emissions from crop residue.

Dear Tom,

Thank you so much for sharing these papers on data on N2O emissions from crop residues application to soils.

I think these data could be extremely useful for the EFDB and could be considered as soon as the upcoming EB meeting in Ghent.

As you mentioned, it would be highly appreciated if Dr. Delgado could complete the data forms for the proposed data. Attached is a blank EB data form. Although the form is largely self-explanatory, attached is a document that could help him better understand the information requirements for various fields. I am, of course, available to reply to any specific queries he might have.

Hope to see you in Ghent!

Best,

Nalin

<<Data_form_20120214.xls>>

<<Instructions_20120214.pdf>>

From: Wirth, Tom [<mailto:Wirth.Tom@epa.gov>]

Sent: 22 October 2013 21:58

To: Nalin Srivastava

Cc: Kiyoto TANABE; Delgado, Jorge

Subject: FW: IPCC - I respectfully submit the following argument for changing two of the factors to assess the N2O emissions from crop residue.

Dear Nalin,

I'm forwarding you some information from Jorge Delgado, a USDA researcher, suggesting that the EFDB consider including some revised factors for the estimation of indirect and direct N2O emissions related to crop residues. Also attached is the supporting information for these recommendations. If there are some additional procedures for having this type of data included in the EFDB I'm sure Jorge could complete that paperwork as well.

You can read his email below but essentially he is suggesting the following:

Ex. 5 - Deliberative Process

I'm working to get my travel approved for the upcoming EFDB meeting so I'll probably see you there.

Cheers,

Tom

Tom Wirth

US Environmental Protection Agency

Climate Change Divison

Tel: 202 343-9313

Mobile: Ex. 6 - Personal Privacy

Wirth.tom@epa.gov

From: Delgado, Jorge [<mailto:Jorge.Delgado@ARS.USDA.GOV>]

Sent: Monday, October 21, 2013 10:48 PM

To: Wirth, Tom; Ogle, Stephen

Cc: Delgado, Jorge; Delgado, Jorge

Subject: RE: IPCC - I respectfully submit the following argument for changing two of the factors to

assess the N₂O emissions from crop residue.

Tom

I respectfully submit the following argument for having the IPCC Emissions Factor Database Team consider changing two of the factors to assess the N₂O emissions from crop residue.

Looking forward to the committees response.

Jorge

////////////////////////////////////

October 21, 2013

Tom Wirth

Member of IPCC Emissions Factor Database Team

Dear Tom,

As requested in previous email communications, I am submitting my recommendations for two of the coefficients used to assess N₂O emissions.

Ex. 5 - Deliberative Process

Ex. 5 - Deliberative Process

Ex. 5 - Deliberative Process

Thank you for giving me the opportunity to present these two recommendations. Please do not hesitate to contact me if you have any questions.

Jorge Delgado,

References

Collins, H.P., J.A. Delgado, , A. Alva and R.F. Follett. 2007. Use of ^{15}N isotopic techniques to estimate nitrogen cycling from a mustard cover crop to potatoes. *Agron J* 99:27–35

De Klein, C., R.S.A. Nova, and S. Ogle. 2006. N_2O emissions from managed soils, and CO_2 emissions from lime and urea application. In: Eggleston S (ed) Guidelines for national greenhouse gas inventories: agriculture, forestry and other land use, vol 4. Intergovernmental Panel on Climate Change, National Greenhouse Inventories Programme, Technical Support Unit, Kanagawa

Delgado, J.A., M.A. Dillon, R.T. Sparks, and R.F. Follett. 2004. Tracing the fate of ^{15}N in a small-grain potato rotation to improve accountability of N budgets. *J. Soil Water Conserv.* 59:271-276.

Delgado, J.A., S. J. Del Grosso, and S. M. Ogle. 2010. ^{15}N Isotopic crop residue cycling studies and modeling suggest that IPCC methodologies to assess residue contributions to N_2O -N emissions should be reevaluated. 2010. *Nutr. Cycl. Agroecosyst.* 86:383–390.

Eggleston S, L. Buendia, and K. Miwa K. 2006. Guidelines for national greenhouse inventories: agriculture, forestry and other land use, vol 4. Intergovernmental Panel on Climate Change, National Greenhouse Inventories Programme, Technical Support Unit, Kanagawa

Jackson, L.E. 2000. Fates and Losses of Nitrogen from a Nitrogen-15-Labeled Cover Crop in an Intensively Managed Vegetable System *Soil Sci. Soc. Am. J.* 64:1404–1412

Toma Y. and R. Hatano. 2007. Effect of crop residue C:N ratio on N_2O emissions from Gray Lowland soil in Mikasa, Hokkaido, Japan. *Soil Sci Plant Nutrit* 53:198–205

From: Delgado, Jorge
Sent: Thursday, August 01, 2013 2:15 PM
To: Wirth, Tom; Ogle, Stephen
Cc: Delgado, Jorge
Subject: RE: IPCC N2O coefficients

Tom

Will do

Jorge

From: Wirth, Tom [<mailto:Wirth.Tom@epa.gov>]
Sent: Thursday, August 01, 2013 2:14 PM
To: Delgado, Jorge; Ogle, Stephen
Subject: RE: IPCC N2O coefficients

Jorge,

Sounds good. Please provide all supporting documentation that the IPCC will also need to evaluate the new factors. Published papers are the best, but perhaps with the paper you included in your email and the additional information you provide they can make a determination on whether to include them in the EFDB.

Tom

Tom Wirth

US Environmental Protection Agency

Climate Change Division

Tel: 202 343-9313

Mobile: 703 399-1594

Wirth.tom@epa.gov

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